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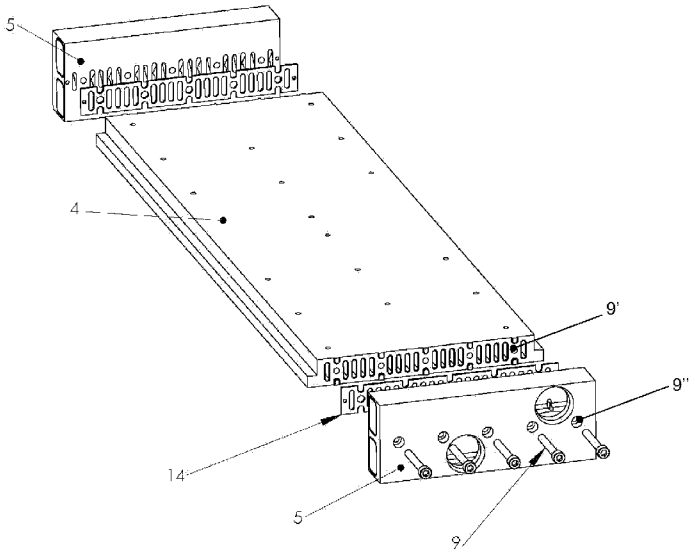


Fig. 3

(57) Abstract: A cooling device comprises a main body (4) and an adapter device (5) arranged at an end (4a) of themain body. The main body is provided with a plurality of channels (6, 7) running from one to the other one of the oppositely located ends of themain body.A further adapter device is arranged at the other end of the main body and each of the adapter devices comprises two separate chambers (10, 11) and, for each of the two separate chambers, an input/output (10a, 11a) in fluid communication with the chamber,and holes (12, 13) providing fluid communication between the chamber and alternating ones of said plurality of channels, thereby providing two separate fluid path systems.

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# COOLING DEVICE AND METHOD FOR THE MANUFACTURING THEREOF

## FIELD OF INVENTION

This invention relates to a cooling device comprising a main body arranged to house electronic circuitry, preferably power electronic circuitry and/or capacitor circuitry, on at least one surface thereof. The invention also relates to a method for the manufacturing of such cooling device.

## BACKGROUND

As is known, operating electronic devices produce heat. This heat should be removed from the devices in order to maintain device junction temperatures within desirable limits. Failure to remove the heat thus produced results in increased device temperatures, potentially leading to thermal runaway conditions. Several trends in the electronics industry have combined to increase the importance of thermal management, including heat removal for electronics devices.

One cooling approach is to use a cooling liquid, such as water or other aqueous fluids, which exhibit superior thermal conductivity and specific heat compared to dielectric liquids. Water-based coolants, however, must be kept from physical contact with electronic devices and interconnects, since corrosion and electrical short circuit problems are likely to result from such contact. Various methods have been disclosed for using water-based coolants, while providing physical separation between the coolant and the electronic devices.

Notwithstanding the above, there remains a large and significant need to provide further useful cooling apparatus enhancements for facilitating cooling of electronic circuit devices such as power electronic circuits, for instance IGBT's which generate large amounts of heat and capacitors which need cooling to ensure a long lifetime.

## SUMMARY OF THE INVENTION

An object of the invention is to provide a cooling device which is capable of providing effective cooling with high flow of cooling fluid.

A further object of the invention is to provide such cooling device which has a low pressure drop over the cooling fluid path.

A still further object of the invention is to provide such cooling device having a main body or heat sink which can be populated with components such as IGBT's and capacitors on opposite surfaces thereof.

A yet further object of the invention is to provide such cooling device having two parallel and separate, i.e. redundant, cooling fluid systems.

A still further object of the invention is to provide such cooling device having capability of providing oppositely directed flows of cooling fluid in the two redundant cooling fluid systems.

A yet further object of the invention is to provide such cooling device having a cost effective design.

A still further object of the invention is to provide a method for the manufacturing of a cooling device which fulfils the above identified objects.

The shortcomings of the prior art are overcome, the above objects are attained, and additional advantages are provided through cooling devices and methods as defined in the appended patent claims.

## BRIEF DESCRIPTION OF DRAWINGS

The invention is described in detail below, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 illustrates in a perspective view the cooling device of the invention having a main body on which electronic components are mounted;

Fig. 2 illustrates in a perspective view the main body of the cooling device of Fig. 1;

Fig. 3 illustrates in an exploded perspective view the cooling device of Fig. 1;

Fig. 4 illustrates in a magnified perspective view a corner portion of the cooling device of Fig. 1;

Fig. 5 illustrates in a magnified perspective view the corner portion of Fig. 4 with a cut through a first channel and a first angled hole which runs downwards as seen from the first channel;

Fig. 6 illustrates in a magnified perspective view the corner portion of Fig. 4 with a cut between the first

and a second channel and between the first and a second angled hole;

Fig. 7 illustrates in a magnified perspective view the corner portion of Fig. 4 with a cut through the second channel and the second angled hole which runs upwards as seen from the second channel; and

Fig. 8 illustrates an adapter device as being comprised in the cooling device of Fig. 1, wherein the first and second angled holes as well as further angled holes are schematically indicated by dashed lines.

## DETAILED DESCRIPTION OF THE INVENTION

The heat sink or cooling device 1 as being illustrated in the drawings is an assembly of essentially one main body 4 and two adapter devices 5 arranged at oppositely located ends 4a, 4b of the main body.

The main body 4, which may be an extruded aluminum profile, is designed as a flat body extending in a horizontal plane in the drawings and is provided with a number of channels 6, 7 running from one to the other one of the oppositely located ends 4a, 4b of the main body 4, in which channels 6, 7 a cooling fluid such as water is flowing during use of the cooling device 1. The main body includes two oppositely located surfaces, wherein at least one of the surfaces is arranged to carry electronic circuitry, preferably power electronic circuitry and/or capacitor circuitry. In Fig. 1 the main body 4 carries IGBT:s 2, which generates large amounts of heat, at a lower surface and capacitors 3, which need cooling to ensure a long lifetime, at an upper surface.

The surface(s) of the main body 4 of the cooling apparatus 1 of the invention can alternatively be arranged to carry other type of components that need effective cooling.

In Figs. 5 and 6 is shown holes 15' arranged for receiving screws or bolts 15 for attachment of electronic components to the main body 4.

Preferably, the channels 6, 7 are located in a single horizontal plane and are essentially parallel to one another. The channels are advantageously narrow, i.e. they have each an elongated cross section extending essentially in a vertical direction, in order to get a suitable thermal contact area between the cooling fluid and the main body 4 and they are of a high number in order to keep a low pressure drop of the cooling fluid and to make it possible to cool a large area even if one of two separate cooling fluid path systems for cooling of the electronic circuitry fails. Some portions 8 of the main body, which are free from channels 6, 7, are reserved for attachment of the adapter devices 5 to the main body 4. These portions may include threaded holes 9' for receiving screws 9 during attachment of the adapter devices 5 to the main body 4. During attachment a gasket 14 is arranged between each of the adapter devices 5 and the main body 4 as can be seen in Fig. 3.

The adapter devices 5 are each preferably also an extruded aluminum profile. The adapter devices 5 comprise each two separate chambers 10, 11 and, for each of the two chambers 10, 11, an input/output 10a, 11a in fluid communication with the chamber 10, 11, and holes

or openings 12, 13 providing fluid communication between the chamber 10, 11 and alternating ones of said plurality of channels 6, 7. Hereby, two separate cooling fluid path systems for cooling of the electronic circuitry located on the main body 4 are provided. The adapter device 5, which is shown in detail in Fig. 8, includes holes 9'' for the attachment of the adapter device 5 to the main body 4.

Advantageously, the separate chambers 10, 11, which may be referred to as lower chambers 10 and upper chambers 11, are elongated extending in a direction essentially perpendicular to a direction in which the channels 6, 7 run and essentially parallel with the surface(s) of the main body 4 arranged to house the electronic circuitry when the cooling device is assembled.

The chambers 10, 11 are formed by covering the end surfaces of the extruded profile with end covers 10b, 11b. These end covers 10b, 11b may be welded or attached by means of screws or other suitable fastening means.

The holes 12, 13 are advantageously formed by milling or drilling and extend essentially in directions which are angled with respect to the horizontal plane so that they can connect the channels 6, 7 lying in the single horizontal plane with the lower and upper chambers 10, 11. The holes (and the angles) are located in a vertical plane parallel with the direction in which the channels 6, 7 run when the cooling device is assembled.

The angles are preferably less than 60°, and more preferably between 40° and 50°, e.g. about 45° to avoid

large pressure drops in the cooling fluid flow regardless of the flow direction.

The angled holes 12, 13 have each an elongated cross section extending essentially in a direction located in the vertical plane parallel with the direction in which the channels 6, 7 run when the cooling device is assembled.

The angled holes 12, 13 may provide fluid communication between one of the chambers 10 of each of the adapter devices and every second of said plurality of channels 6 and between the other one of the chambers 11 of each of the adapter devices and every second of said plurality of channels 7.

The cooling device can be designed so that all even channels 6 are arranged to pass cooling fluid for one of the two cooling fluid path systems and all odd channels 7 are arranged to pass cooling fluid for the other one of the cooling fluid path systems. The two cooling fluid path systems are totally independent of each other and if one fails due to leakage somewhere in the system, the other will continue to cool the same surface, although it might be with limited performance.

Such design is illustrated in the drawings. Fig. 5 illustrates in a magnified perspective view the corner portion of the cooling device with a cut through a first channel 6 and a first angled hole 12. The hole 12 is tilted or runs downwards as seen from the first channel 6 to obtain fluid communication with the lower chamber 10. Fig. 7 illustrates the same corner portion, but with a cut through a second channel 7 and a second angled

hole 13. The hole 13 is tilted or runs upwards as seen from the second channel 7 to obtain fluid communication with the upper chamber 11.

It shall be appreciated that the cooling device can be designed for each of the two fluid cooling path systems to pass cooling fluid through the channels in any direction. Fig. 2 illustrates an embodiment wherein cooling fluid is passed through said two separate cooling fluid path systems in opposite directions as indicated by the arrows.

The present invention provides a cooling device which can be equipped with two redundant cooling fluid path systems. The cooling fluid input/output as well as the cooling fluid separation are provided for by the adapter devices arranged at the side ends of the main body of the cooling device. The cooling may be bidirectional by means of flowing cooling fluid in opposite directions in the two cooling fluid path systems.

The provision of many parallel narrow channels results in effective cooling with high flow of cooling fluid. The angled holes of the adapter devices provides for low pressure drops.

The design of the cooling device is cost effective and uses a minimum number of parts and manufacturing steps.

It shall be appreciated that an alternative embodiment of the invention differs from the above described embodiment in that each of the adapter devices includes more than two chambers, wherein each of the adapter devices comprises, for each of the chambers, an

input/output in fluid communication with the chamber, and holes providing fluid communication between the chamber and alternating ones of the channels of the main body. Hereby, more than two separate cooling fluid path systems for cooling may be provided to further enhance safety of the cooling operation of the device.

In another embodiment only one adapter device is provided. The channels may in such embodiment be interconnected at the end of the main body wherein the adapter device is not located. The interconnections may be formed so that adjacent channels are interconnected, thereby obtaining a single cooling fluid path system. Alternatively, the cooling fluid is lead away from the cooling apparatus at the end of the main body wherein the adapter device is not located.

It shall further be pointed out that the various parts of the cooling apparatus may be manufactured by other techniques than extrusion. In particular, the adapter devices may each be comprised of several parts which are soldered or welded together, or mounted together.

PATENT CLAIMS

1. A cooling device comprising a main body (4) and an adapter device (5) arranged at one (4a) of two oppositely located ends (4a, 4b) of said main body, wherein

- the main body is provided with a plurality of channels (6, 7) running from one to the other one of the oppositely located ends of said main body, **characterized in**

- a further adapter device arranged at the other one of the oppositely located ends of said main body, wherein each of the adapter devices comprises two separate chambers (10, 11) and, for each of the two separate chambers, an input/output (10a, 11a) in fluid communication with the chamber, and holes (12, 13) providing fluid communication between the chamber and alternating ones of said plurality of channels, thereby providing two separate fluid path systems.

2. The cooling device of claim 1, wherein said main body is arranged to house electronic circuitry, preferably power electronic circuitry and/or capacitor circuitry, on at least one surface thereof.

3. The cooling device of claim 1 or 2, wherein the main body is flat extending in a horizontal plane, the separate chambers of each of the adapter devices are comprised of a lower and an upper chamber, and the holes are extending essentially in directions which are angled with respect to said horizontal plane.

4. The cooling device of claim 3, wherein said angles are less than 60°, preferably between 40° and 50°, e.g. about 45°.

5. The cooling device of claim 3 or 4, wherein said angles are located in a vertical plane parallel with a direction in which said channels run.

6. The cooling device of any of claims 1-5, wherein the holes provide fluid communication between one of the chambers of each of the adapter devices and every second of said plurality of channels and between the other one of the chambers of each of the adapter devices and every second of said plurality of channels.

7. The cooling device of any of claims 1-6, wherein said holes have each an elongated cross section extending essentially in a direction located in a vertical plane parallel with a direction in which said channels run.

8. The cooling device of any of claims 1-7, wherein said channels are located in a single plane.

9. The cooling device of any of claims 1-8, wherein said channels are essentially parallel to one another.

10. The cooling device of any of claims 1-9, wherein said channels have each an elongated cross section extending essentially in a direction perpendicular to a surface of said main body.

11. The cooling device of any of claims 1-10, wherein the chamber of the adapter device is elongated extending in a direction essentially perpendicular to a

direction in which said channels run and essentially parallel with a surface of the main body.

12. The cooling device of any of claims 1-11 comprising means provided for passing cooling fluid through said two separate fluid path systems in opposite directions.

13. The cooling device of any of claims 1-12, wherein said main body is arranged to house electronic circuitry on two oppositely located surfaces thereof.

14. A method for the manufacturing of a cooling device comprising the steps of:

- providing a main body (4) with a plurality of channels (6, 7) running from one to the other one of oppositely located ends of the main body;

- providing an adapter device (5) with two separate chambers (10, 11) and, for each of the two chambers, with an input/output (10a, 11a) and holes (12, 13) in fluid communication with the chamber; and

- attaching said adapter device (5) to the main body at one of the oppositely located ends (4a, 4b) thereof, with the side at which the holes are located facing the main body, wherein the adapter device and the main body are aligned to one another and the channels and holes are provided so as to obtain fluid communication between each of the chambers and alternating ones of said plurality of channels, **characterized in** that

- a further adapter device (5) is provided with two separate chambers (10, 11) and, for each of the two

chambers, with an input/output (10a, 11a) and holes (12, 13) in fluid communication with the chamber; and

- said further adapter device (5) is attached to the main body at the other one of the oppositely located ends (4a, 4b) thereof, with the side at which the holes are located facing the main body, wherein the further adapter device and the main body are aligned to one another and the channels and holes of the further adapter device are provided so as to obtain fluid communication between each of the chambers of the further adapter device and alternating ones of said plurality of channels.

15. The method of claim 14, wherein said main body is arranged to house power electronic circuitry on at least one surface thereof.

16. The method of claim 14 or 15, wherein the main body is provided to be flat extending essentially in a horizontal plane, the separate chambers of each of the adapter devices are provided as a lower and an upper chamber, and the holes are provided to extend essentially in directions which are angled with respect to said horizontal plane.

17. The method of any of claims 14-16, wherein the main body with the channels is formed by means of extrusion.

18. The method of claims 14-17, wherein the adapter devices with the chambers are formed by (i) extruding and attaching end covers to the extruded structure,

thereby forming the chambers; and (ii) milling or drilling the holes.

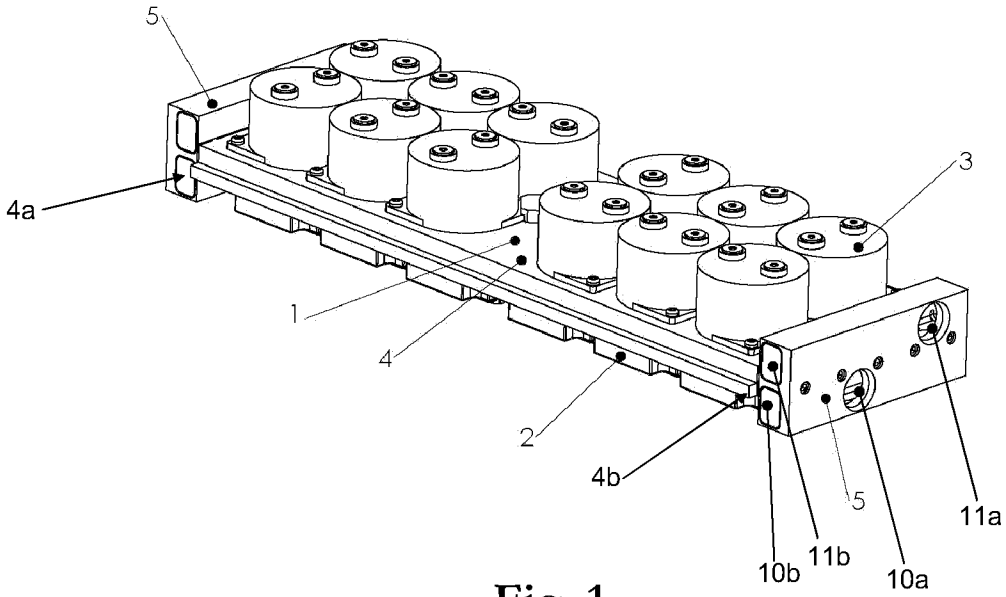


Fig. 1

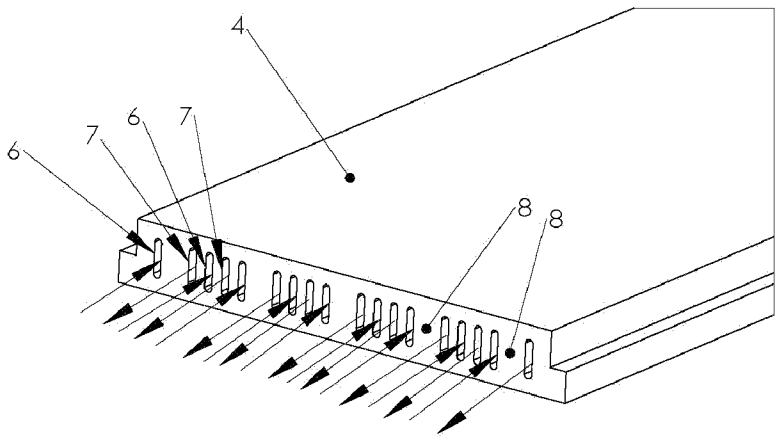


Fig. 2

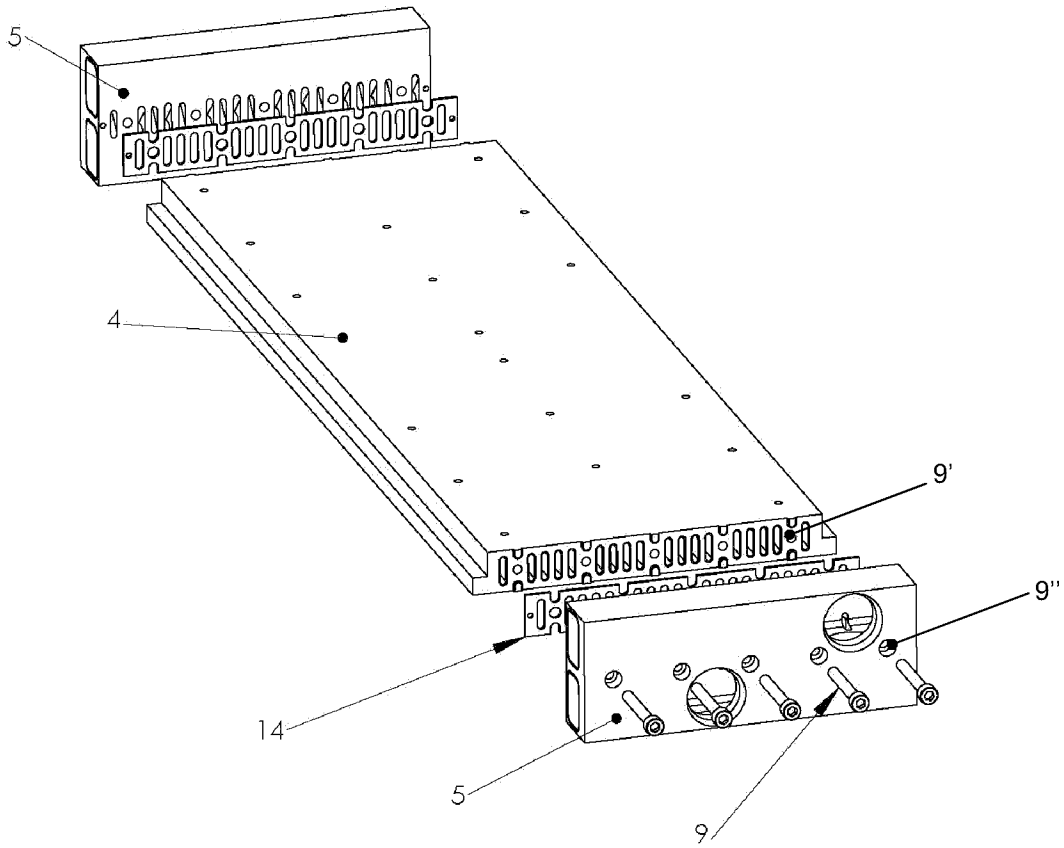


Fig. 3

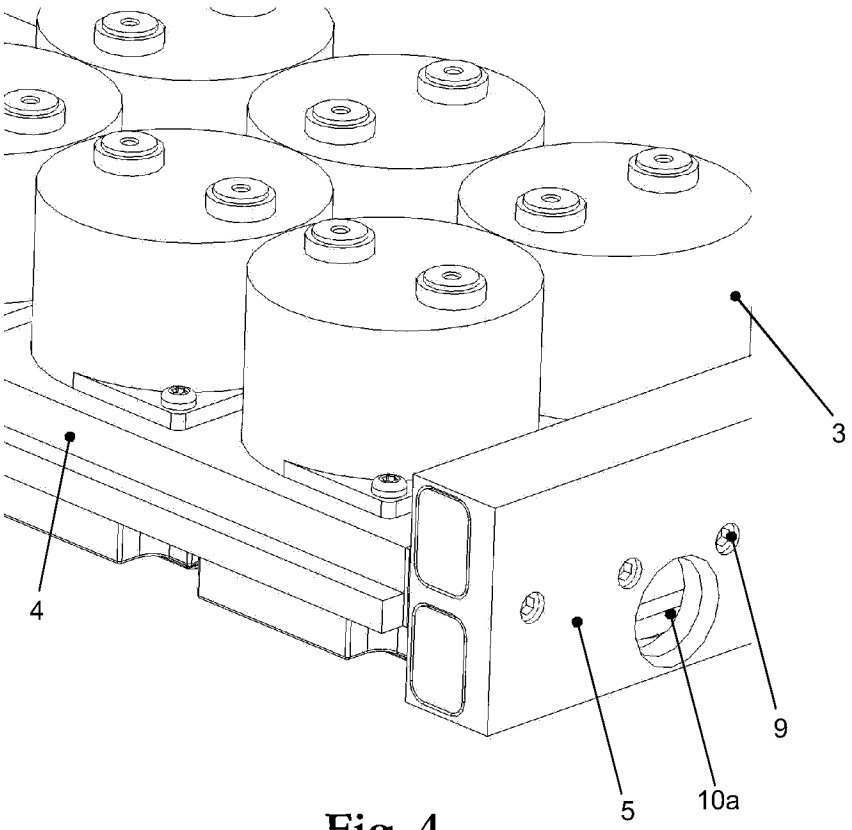


Fig. 4

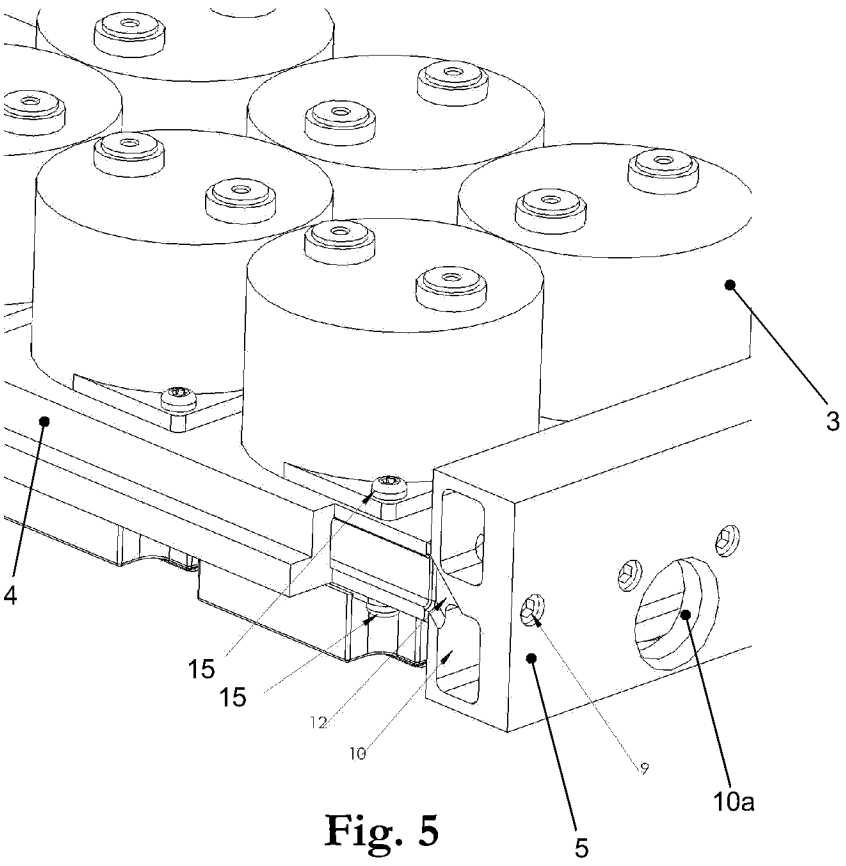


Fig. 5

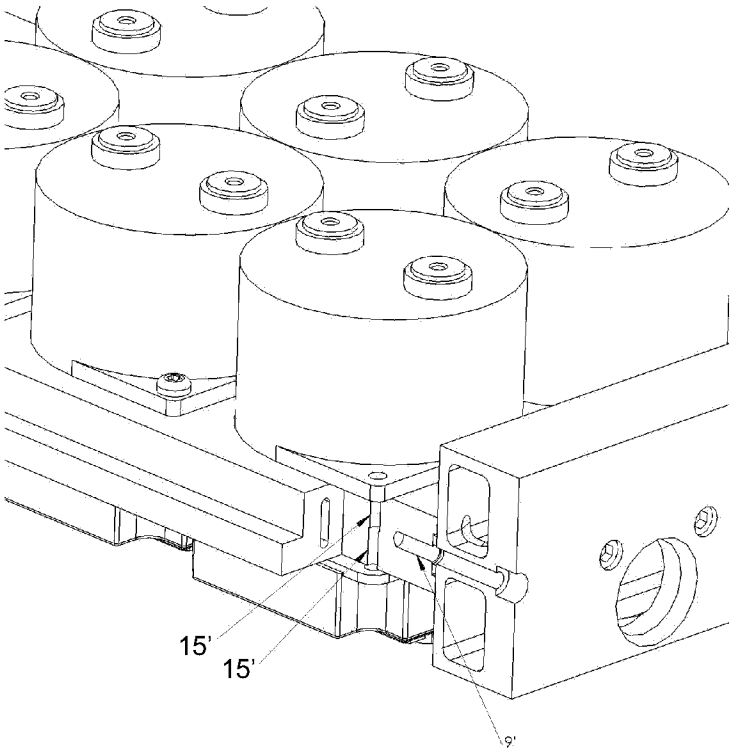


Fig. 6

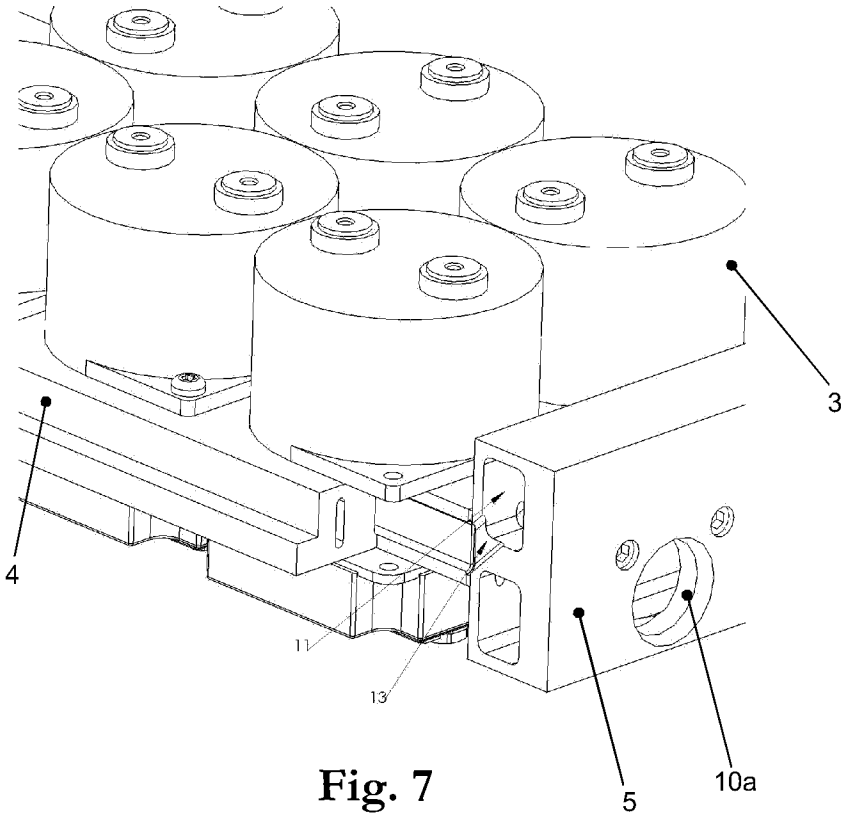


Fig. 7

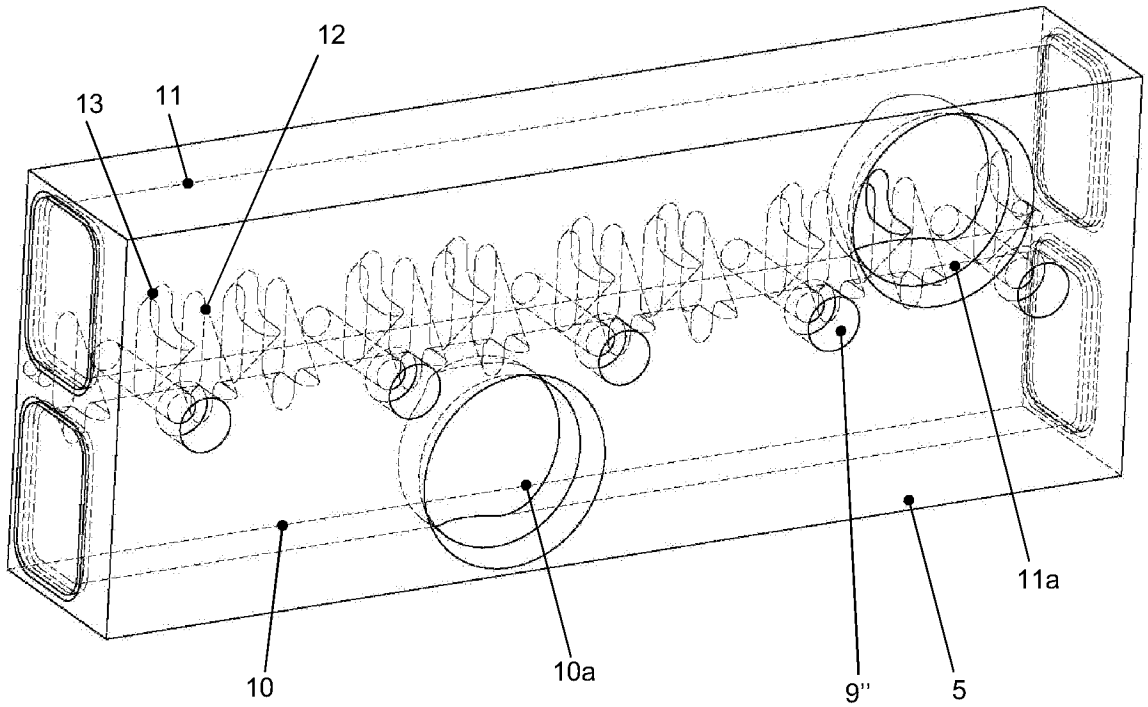


Fig. 8

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2009/050260

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H05K, H01L, F28D, F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

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EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | JP 2000216314 A, TOYOTA MOTOR CORP, 2000-08-04: (abstract) Retrieved from: EPODOC database; Original document: Fig. 1-5 | 1-18 |
| A | EP 1089604 A1 (ELECTRIC BOAT CORPORATION), 4 April 2001 (04.04.2001), figures 1,2, abstract, paragraphs (0012)-(0013) | 1-18 |
| A | US 20060011332 A1 (INOUE ET AL), 19 January 2006 (19.01.2006), figures 4,5, abstract, paragraphs (0061)-(0066) | 1-18 |

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 28 May 2009 | 12 -06- 2009 |
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Cited literature, if any, will be enclosed in paper form.

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| EP | 1089604 | A1 | 04/04/2001 | JP | 2001127478 A | 11/05/2001 |
| | | | | US | 6230791 B | 15/05/2001 |
| US | 20060011332 | A1 | 19/01/2006 | NONE | | |