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(54) **Title**: ADVANCED HEAT EXCHANGER WITH INTEGRATED COOLANT FLUID FLOW DEFLECTOR

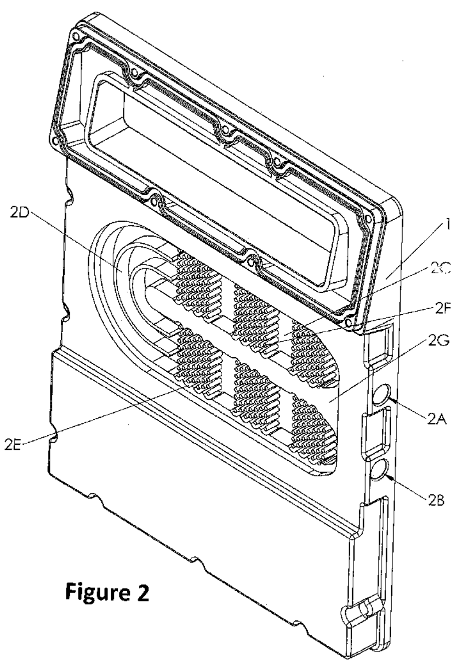

Figure 2

(57) **Abstract**: The Advanced Heat Exchanger with Integrated Coolant Fluid Flow Deflector for liquid cooled applications comprise the heat sink (2) with integrated coolant fluid flow deflector (2D) for controlled deflection of coolant fluid flow, which is selectively focused and guided to the local heat sources (4A) in the power electronics application. The invention is based on insight that cooling fluid flow is selectively guided to the local heat sources (4A) by integrated fluid flow deflector (2D), wherein such a heat sink (2) is part of the power electronics enclosure (1) or part of the power electronics base plate (3).

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ADVANCED HEAT EXCHANGER WITH INTEGRATED COOLANT FLUID FLOW DEFLECTOR

Field of the Invention

The object of this patent application relates to the heat exchangers as cooling system of power electronics. Such heat exchangers as Power Module Coolers are in the preferential embodiment designed as Pin Fin Coolers for high power applications in Motor and Motion Control, Hybrid Electric Vehicles and other Power Module systems.

Background of the Invention

Heat sinks are so-called extended surfaces that have been used to enhance cooling of heat dissipating surfaces. Such heat sinks have been fabricated in a number of designs. The designs are such as to decrease fluid flow impedance through the heat sink and thereby improve heat dissipation performance. The pin fin heat sink is of particular interest because it is one of the commonly used heat sinks.

The technological problem addressed by this patent-application is the lack of a heat exchanger that is easy to fabricate and manufacture, whilst maintaining a minimal number of components thus ensuring the low cost overall system implementation.

A significant number of relevant solutions are listed in the International Patent register. The following two describe the solutions that describe the state of the art in this area of technology.

According to US2008/0066888A1 (Danaher Motion Stockholm AB), the heat exchanger comprise the array of pin fins which are various in shape and position and thus some of those pin fins are arranged and acting as the coolant fluid deflector. Yet another solution as disclosed in US US6173758B1 (General Motors Corporation) incorporates plurality of extended straight pin fins various in shape and arranged in semicircular pattern, which are acting as coolant fluid deflector by forming the quasi channel for cooling fluid flow by drag force.

Pressure drop across a pin fin heat sink is one of the key variables that govern the thermal performance of the heat sink. Thus, the main and crucial disadvantage of stated solutions from prior art is that they are creating the flow deflection with unnecessary pressure drop and drag force, which contributes to higher pressure drop and pressure distribution distortion within the heat sink main cavity. Thus a problem of prior art pin fin heat sinks is to find the optimum configuration for controlled deflection of coolant fluid with minimum pressure drop.

Summary of the Invention

This invention relates to a cooling system having one or more pin fins for an electric motor controller. An object of the present invention is to provide a heat sink for liquid cooled applications with controlled deflection of coolant fluid flow, which is selectively focused and guided to the local heat sources in the power electronics applications by flow guide arrangement. The invention is based on insight that cooling fluid flow is selectively guided to the local heat sources by integrated fluid flow deflector. The integrated coolant fluid guide is herein after referred to as coolant fluid flow deflector.

Advanced heat exchanger with integrated coolant fluid flow deflector includes a base, i.e. first surface having the plurality of pin fins and at least one deflector element perpendicular to and protruding there from. In preferential embodiment pin fins are in staggered rows whereby the pin fins could equally be in aligned rows on base surface without departing from the spirit or scope of the invention.

Second aspect of the present invention is to provide the inlet and outlet aperture with maximum cross section area, while maintaining the minimum height of the heat sink. Thus the shape of the inlet and outlet aperture cross section is continuously transformed from circle to semicircle shape for providing the minimum pressure drop at coolant passage.

Yet another aspect of the present invention is to provide the boundary fin for main cavity side wall, which should effectively prevent the laminar coolant flow passing by in the gap between the cavity side wall and pin fin array.

Preferred embodiments of the present invention will now be described with reference to the accompanying drawings of advanced heat exchanger with integrated cooling fluid deflector in the reverse and throughout passageway embodiments. The reverse cavity passageway type heat exchanger (herein after referred to as first embodiment) is the heat exchanger with U turn segment where the coolant fluid flow turns its direction for about 180° at the end of the partition wall, toward to the outlet opening direction, thus the inlet and outlet openings are situated on the same side of the heat sink. As alternative, the throughout cavity passageway type heat exchanger (herein after referred to as second embodiment) is one with the inlet opening on the one side, and outlet opening situated on the other side of the heat sink.

Brief description of the drawings

Figure 1 is an isometric (back side) view of a pin fin heat exchanger with integrated deflector (2D) embodying a first embodiment of the present invention. The following items are shown and marked in Figure 1: enclosure (1) of power electronics with integrated heat sink (2); inlet (2A) and outlet (2B) openings; power electronics base plate (3); and power module (4) with plurality of local heat sources (4A), where for clarity of the figure only one random local heat source (4A) is labeled, and casing of power electronics is not shown.

Figure 2 is an isometric (front side) view of a pin fin heat exchanger with integrated deflector (2D) embodying a first embodiment of the present invention. The following items are shown and marked in Figure 2: enclosure (1) of power electronics with integrated heat sink (2); inlet (2A) and outlet (2B) openings; main cavity (2C) of the heat sink; semicircular deflector (2D) within U turn segment for forming the reverse cavity passageway; boundary fin (2E); pin fin (2F) array, where for clarity of the figure only one random pin fin in the array is labeled; and cavity partition wall (2G).

Figure 3 is a top plan view of a pin fin heat exchanger with integrated deflector (2D) embodying a first embodiment of the present invention. For easier understanding the hidden edges of heat exchangers interior are visible and marked with dashed lines. The following items are shown and marked in Figure 3: enclosure (1) of power electronics with integrated heat sink (2); inlet (2A) and outlet (2B) openings; main cavity (2C) of the heat sink; semicircular deflector (2D) within U turn segment for forming the reverse cavity passageway; boundary fin (2E); pin fin (2F) array, where for clarity of the figure only one random pin fin in the array is labeled; cavity partition wall (2G); power electronics base plate (3); and power module (4) with plurality of local heat sources (4A), where for clarity of the figure only one random local heat source (4A) is labeled.

Figure 4 is a top plan view of the heat sink (2) segment illustrating coolant fluid flow, where for clarity of the figure, elements of first embodiment are not labeled again. For easier understanding the primary coolant fluid flow (P) and one of three secondary coolant fluid flows (S) is marked on figure 4. Furthermore, detail (DET-A) for figure 5 is marked on figure 4.

Figure 5 is a top plan detailed view (DET-A) of the heat sinks (2) as marked on figure 4, where for clarity of the figure, elements of first embodiment are not labeled again. For easier understanding the primary coolant fluid flow (P) at inlet (2A) aperture is marked on figure 5.

Figure 6 is an isometric (front side) view of a pin fin heat exchanger with integrated deflector (2D) embodying a second embodiment of the present invention. The following items are shown and marked in Figure 6: enclosure (1) of power electronics with integrated heat sink (2); inlet (2A) and outlet (2B) openings; main cavity (2C) of the heat sink; splitting deflector (2D); boundary fin (2E); and pin fin (2F) array, where for clarity of the figure only one random pin fin in the array is labeled.

Figure 7 is a top plan view of a pin fin heat exchanger with integrated deflector (2D) embodying a second embodiment of the present invention. For easier understanding the hidden edges of heat exchangers interior are visible and marked with dashed lines. The following items are shown and marked in Figure 7: enclosure (1) of power electronics with integrated heat sink (2); inlet (2A) and outlet (2B) openings; main cavity (2C) of the heat sink; splitting deflector (2D); boundary fin (2E); pin fin (2F) array, where for clarity of the figure only one random pin fin in the array is labeled; power electronics base plate (3); and power module (4) with plurality of local heat sources (4A), where for clarity of the figure only one random local heat source (4A) is labeled.

Figure 8 is a top plan view of the heat sink (2) segment illustrating fluid flow, where for clarity of the figure, elements of second embodiment are not labeled again. For easier understanding the primary coolant fluid flow (P) and one of two secondary coolant fluid flows (S) is marked on figure 8. Furthermore, the scope of detail (DET-B) for figure 9 is marked on figure 8.

Figure 9 is a top plan detailed view (DET-B) of the heat sink (2) as marked on figure 8, where for clarity of the figure elements of second embodiment are not labeled again. For easier understanding the primary coolant fluid flow (P) and secondary coolant fluid flow (S) is marked on figure 9.

Referring to the first preferential embodiment the coolant fluid channel within the main cavity (2C) of the heat sink (2) is designed as channel with integrated U turn segment, in which the coolant fluid flow is turned by approx. 180° relative to the inlet (2A), towards to the outlet (2B) aperture. While the plurality of pin fins (2F) and the deflector (2D) is oriented perpendicular relative to the electronics base plate (3), the deflector (2D) and pin fins (2F) can be either part of the heat sink (2) or part of the electronics base plate (3). The height of the deflector (2D) is approximately the same as the height of the pin fin (2F). Thus the deflector (2D) is actually internal quasi wall of the heat sink (2) main cavity (2C), which forces the coolant fluid flow to follow the predetermined path with focus on the local heat sources (4A). The maximum wall thickness of the fluid flow deflector (2D) at the junction with the first surface is equal to the diameter of inscribed circle of the single pin fin (2F) cross section at the junction with the first surface.

In exposed embodiment the inlet aperture is designed as channel with changeable shape of its cross section to provide the maximum diameter for inlet (2A) and outlet (2B) fitting installation, thus achieving the minimum pressure drop value. Therefore the inlet (2A) and outlet (2B) aperture is designed as circular channel on outer side (side of the fitting mounting) and semicircular channel on inner side (the side of the heat sinks (2) main cavity (2C)). The reason for semicircular shape of inlet (2A) and outlet (2B) aperture on the inner side is the height of the pin fins (2F), which is in the most cases lower in value than the diameter of the fitting. According to the first preferential embodiment, where the pin fin (2F) array and deflector (2D) configuration is symmetrical relative to the coolant fluid flow direction, the position of the inlet (2A) and outlet (2B) aperture is nevertheless the same. Thus the inlet (2A) aperture in the first preferential embodiment can be actually the outlet (2B) aperture, or vice versa. According to the second preferential embodiment, the fluid flow cavity (2C) is not symmetrical and therefore the inlet (2A) and outlet (2B) aperture position is exactly defined with orientation of utilized deflector (2D).

The heat sink in exposed embodiments comprises the pin fins (2F), which are in preferential embodiment cylindrical in shape. It can be understood, that the pin fins (2F) can equally be also conical, elliptical, diamond, raindrop, semicircular, crescent moon type or any other shape. Furthermore, the disclosed heat sink (2) with integrated pin fins (2F) and deflector (2D) is in its preferential embodiment made of aluminum, but it can be also made of any other relevant material, such as copper, brass, copper/nickel, aluminium/ brass, carbon steel and stainless steel.

To provide the solution for preventing the laminar coolant flow passing by the pin fins (2F), positioned near the side wall, the preferential embodiment further comprise the boundary fins (2E) integrated into the agitated side wall of the heat sinks (2) main cavity. Consequently the passing by coolant fluid flow is forced to follow and hit the pin fin (2F) array configuration which contributes to enhanced efficiency of the heat sink (2). The boundary fin (2E) is actually designed as row of pin fins integrated into the cavity's (2C) side wall, thus the pattern of the boundary fin (2E) is defined and dictated by the main, i.e. primary pattern of the pin fin (2F) array.

Referring to the second preferential embodiment the deflector (2D) is designed as coolant fluid flow splitting wall, which splits the primary coolant fluid flow (P) into few secondary coolant fluid flows (S) that follows the predetermined path with focus on the local heat sources (4A). Thus the deflector (2D) in the second embodiment is designed as primary coolant fluid flow (P) splitter, which splits the main fluid flow into at least two secondary fluid flows (S). Furthermore the secondary fluid flows (S) engages the local heat sources (4A) with maximum cooling flow rate at maximum velocity possible, whereby the pressure drop is minimized as well, therefore such arrangement is consequently increasing the heat dissipation efficiency of the heat sink (2).

In the foregoing description those skilled in the art will readily appreciate that modifications may be made to the invention without departing from the concepts disclosed herein. Such modifications are to be considered as included in the following claims, unless these claims expressly state otherwise.

We claim:

1. A pin fin cooling system with integrated coolant fluid flow deflector (2D), comprising: at least one first surface defining at least a base portion of the cooling system; at least one pin fin (2F) array extending from the at least one first surface; at least one coolant fluid flow deflector (2D) extending from the at least one first surface, wherein the coolant fluid flow deflector (2D) splits the primary coolant fluid flow (P) into at least two secondary fluid flows (S) that follows the predetermined path with focus on local heat sources (4A); wherein the maximum wall thickness of the fluid flow deflector (2D) at the junction with the first surface is equal to the diameter of inscribed circle of the single pin fin (2F) cross section at the junction with the first surface; and at least one boundary fin (2E) extending from the first surface, wherein the boundary fin (2E) is generated as row of merged pin fins (2F) positioned in the shape of a spline, which correspond and match the pin fin (2F) pattern; wherein the boundary fin (2E) consequently forces the coolant fluid flow to follow the boundary fin (2E) and pin fin (2F) pattern and thus hit the pin fins (2F) surface which contributes to enhanced efficiency of the heat sink (2).

2. A pin fin cooling system of claim 1, wherein the first surface of a cooling system is a part of the heat sink (2); wherein the heat sink (2) is part of the power electronics enclosure (1); wherein the boundary fin (2E) is integrated into the agitated side wall of heat sink (2) in main cavity (2C); wherein the boundary fin (2E) is designed as row of merged pin fins (2F) integrated into the cavity's (2C) side wall, thus the design and the pattern of the boundary fin (2E) is defined and dictated by the primary pattern of the pin fin (2F) array; wherein the inlet (2A) and outlet (2B) aperture channel is designed as channel with changeable shape of its cross section for providing the diameter for inlet (2A) and outlet (2B) fitting installation, which is in diameter value greater than the height of the pin fins (2F), consequently achieving the minimum pressure drop value at entrance and exit of coolant fluid flow; wherein the inlet (2A) and outlet (2B) aperture is designed as circular channel on outer side of the enclosure (1) and semicircular channel on inner side in the main cavity (2C).

3. A pin fin cooling system of claim 2, wherein the coolant fluid flow deflector (2) is designed as U turn segment of the heat sink (2); wherein the U turn segment comprise at least one deflector (2D) for generating and providing the passage for secondary coolant fluid flow (S); wherein the U turn segment turns the coolant fluid flow within the deflector (2D) for about 180° around the U turn segment centre, preferably positioned at the end of the partition wall (2G), which directs the coolant fluid flow toward the outlet (2B) aperture.

4. A pin fin cooling system of claim 1, wherein the first surface of a cooling system is a part of the heat sink (2); wherein the heat sink (2) is part of the power electronics base plate (3); wherein the power electronics base plate (3) further comprise local heat sources (4A) of the power module (4).

5. A pin fin cooling system of claim 3 and 4, wherein the shape of the pin fin (2F) is: conical, elliptical, diamond, semicircular, raindrop or crescent moon shape type.

6. A pin fin cooling system of claim 5, wherein the heat sink (2) is made of: aluminium, copper, brass, copper/nickel, aluminium/brass, carbon steel or stainless steel material.

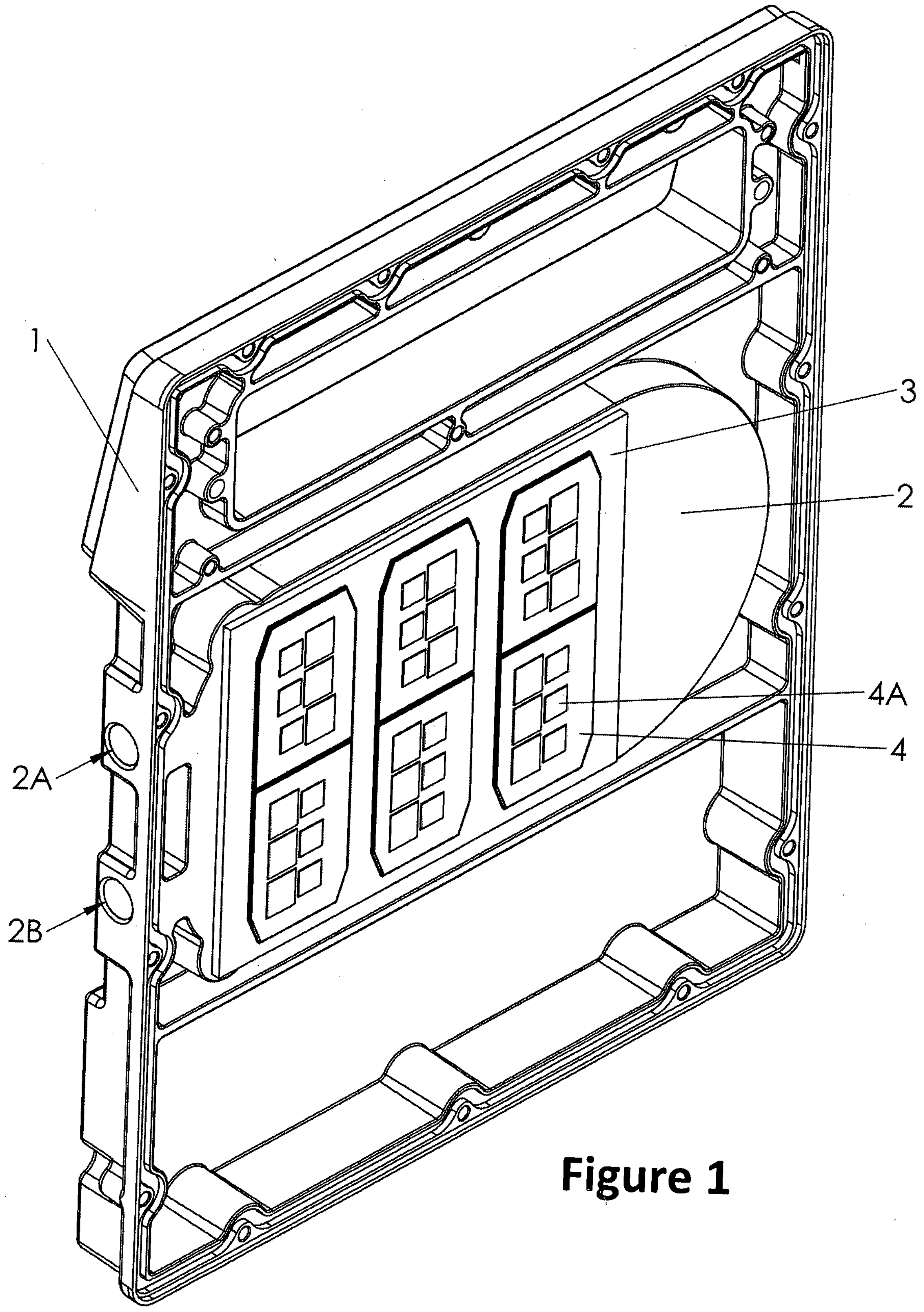

Figure 1

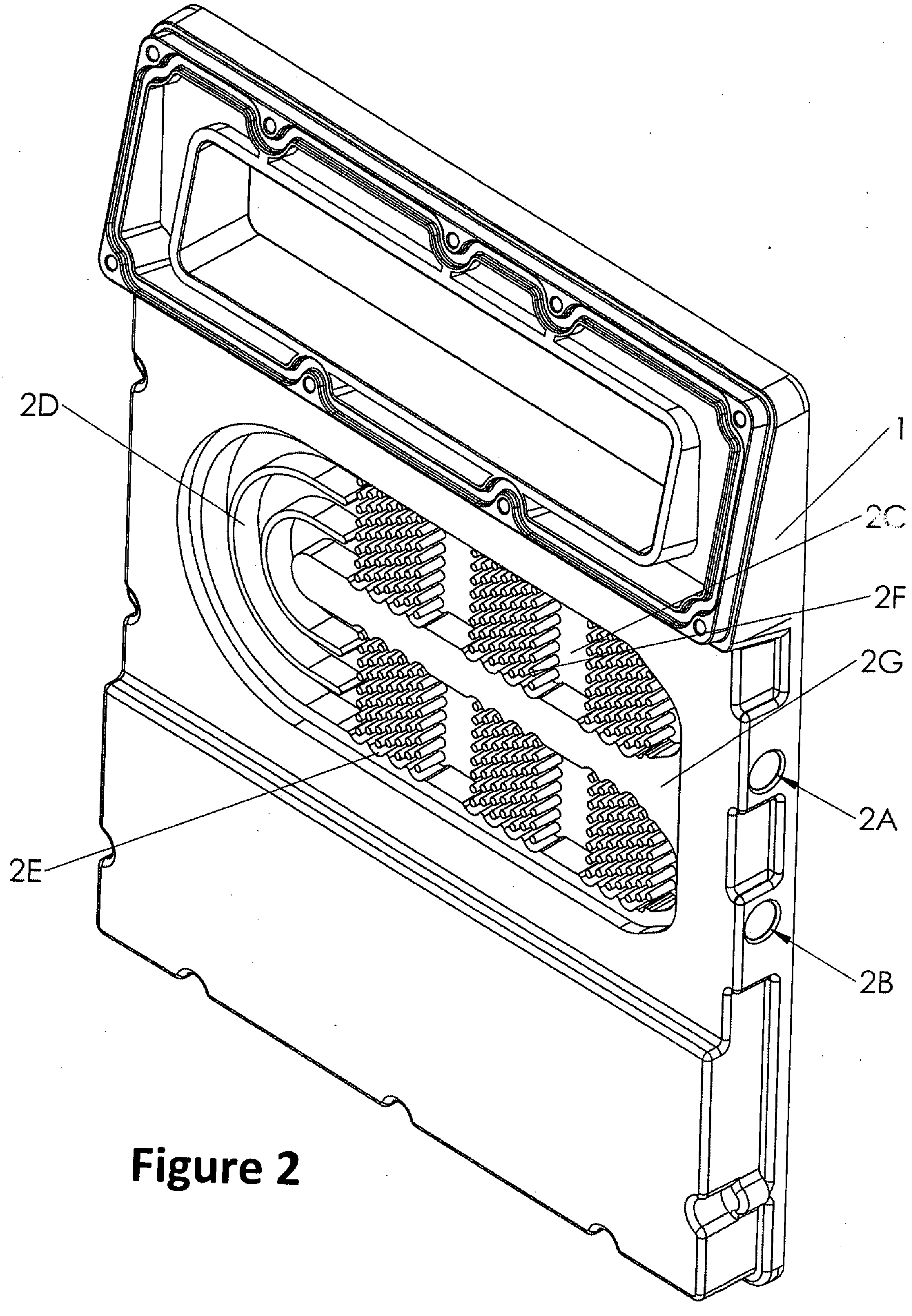

Figure 2

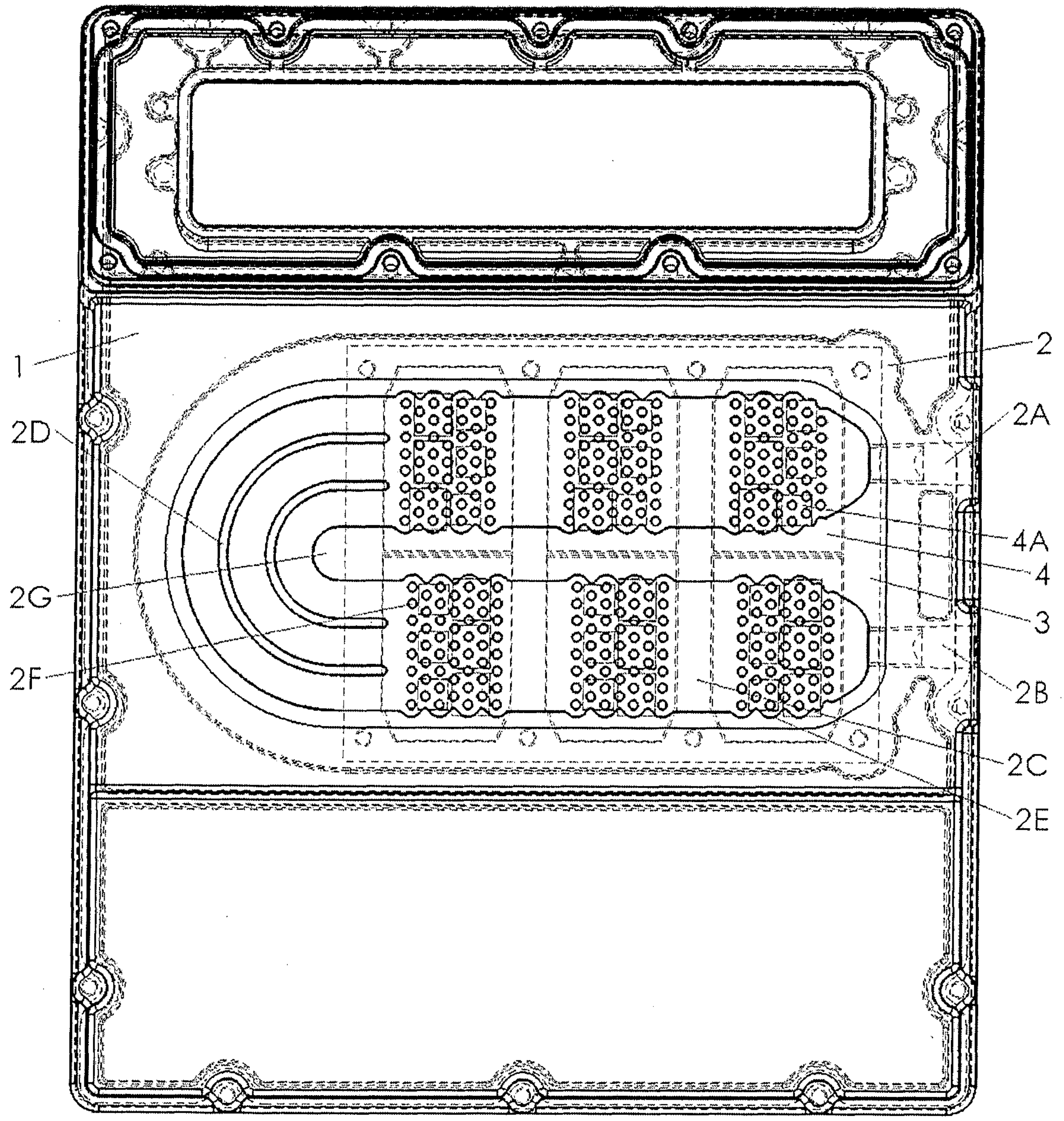

Figure 3

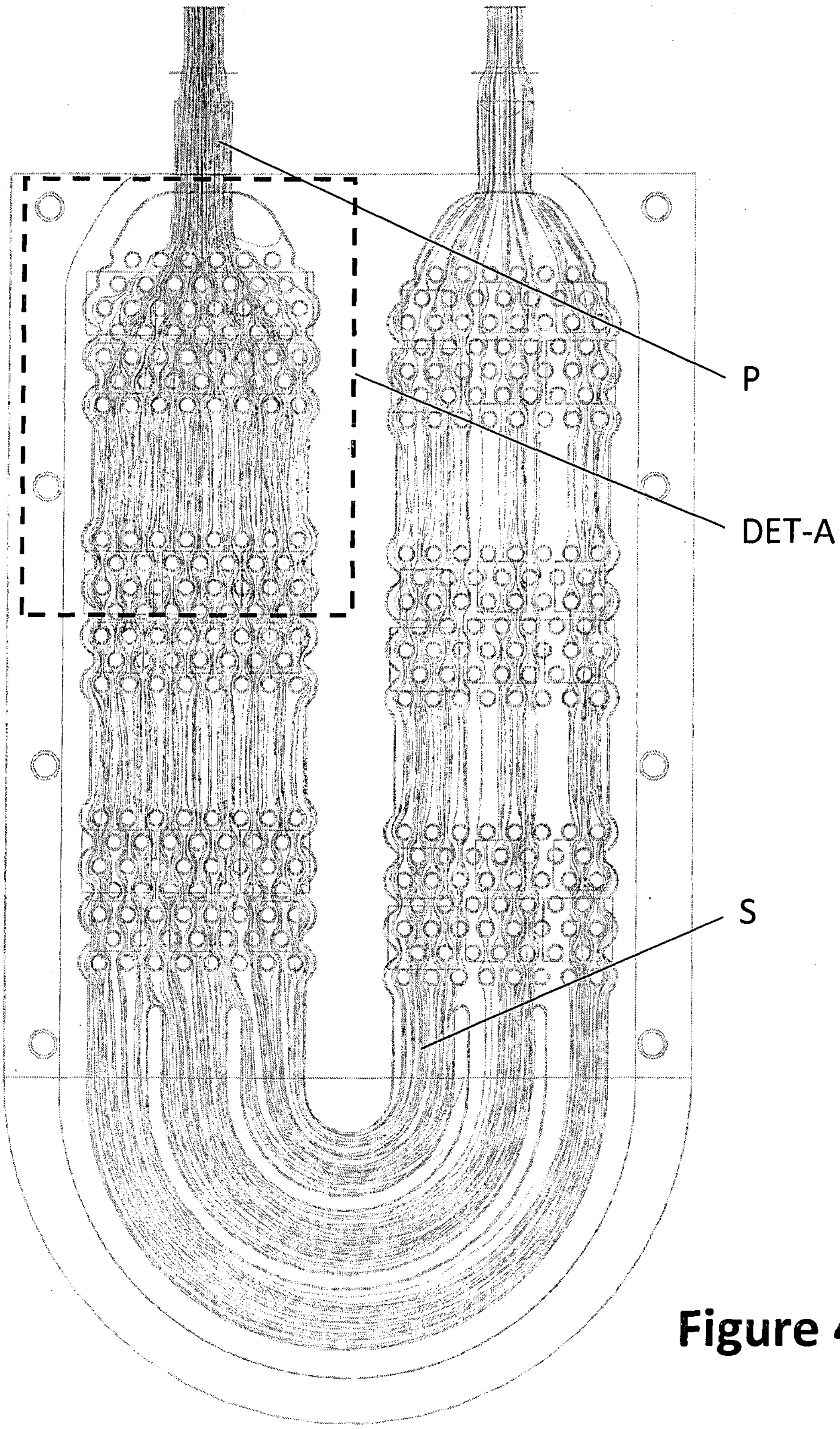

Figure 4

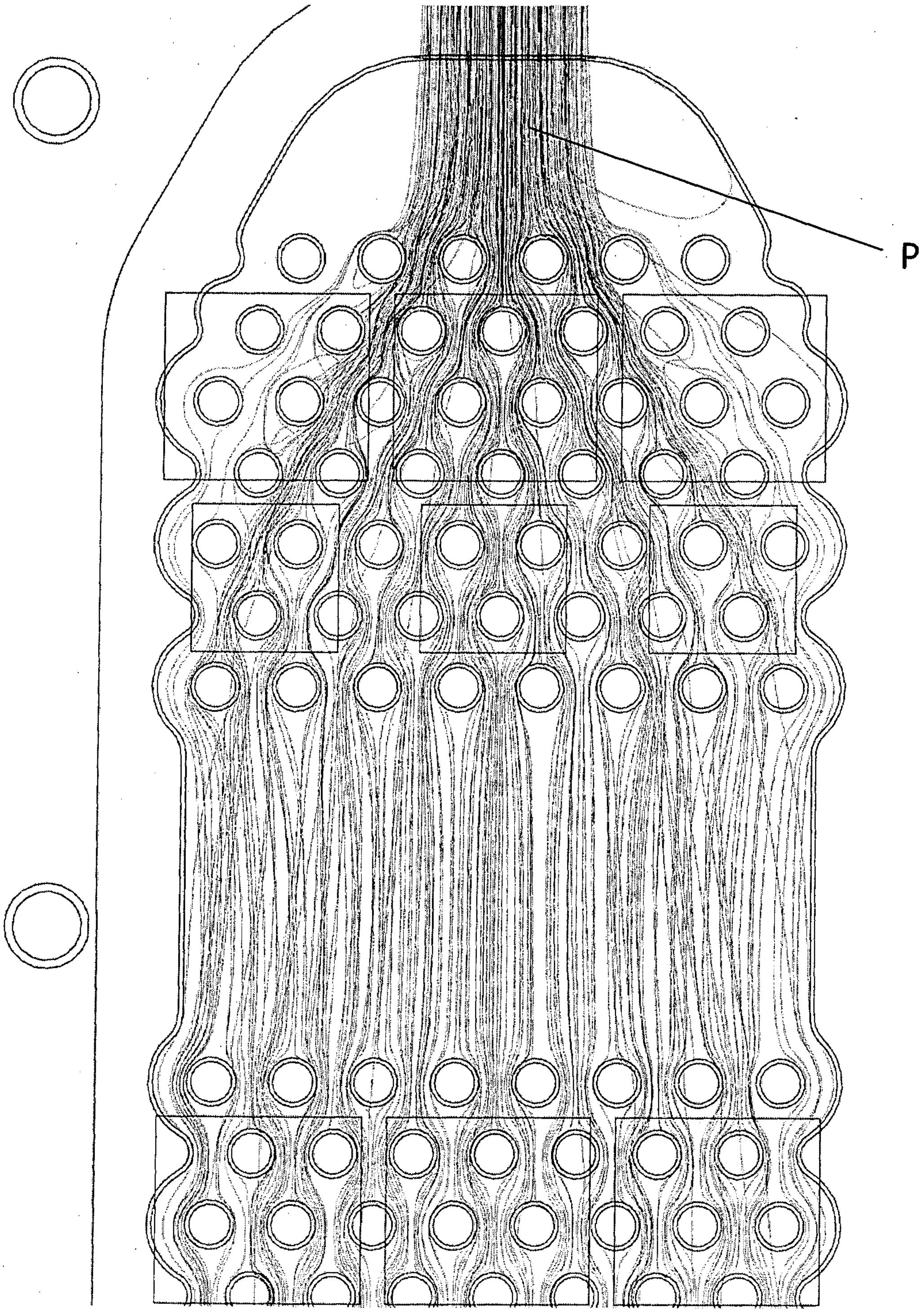

Figure 5

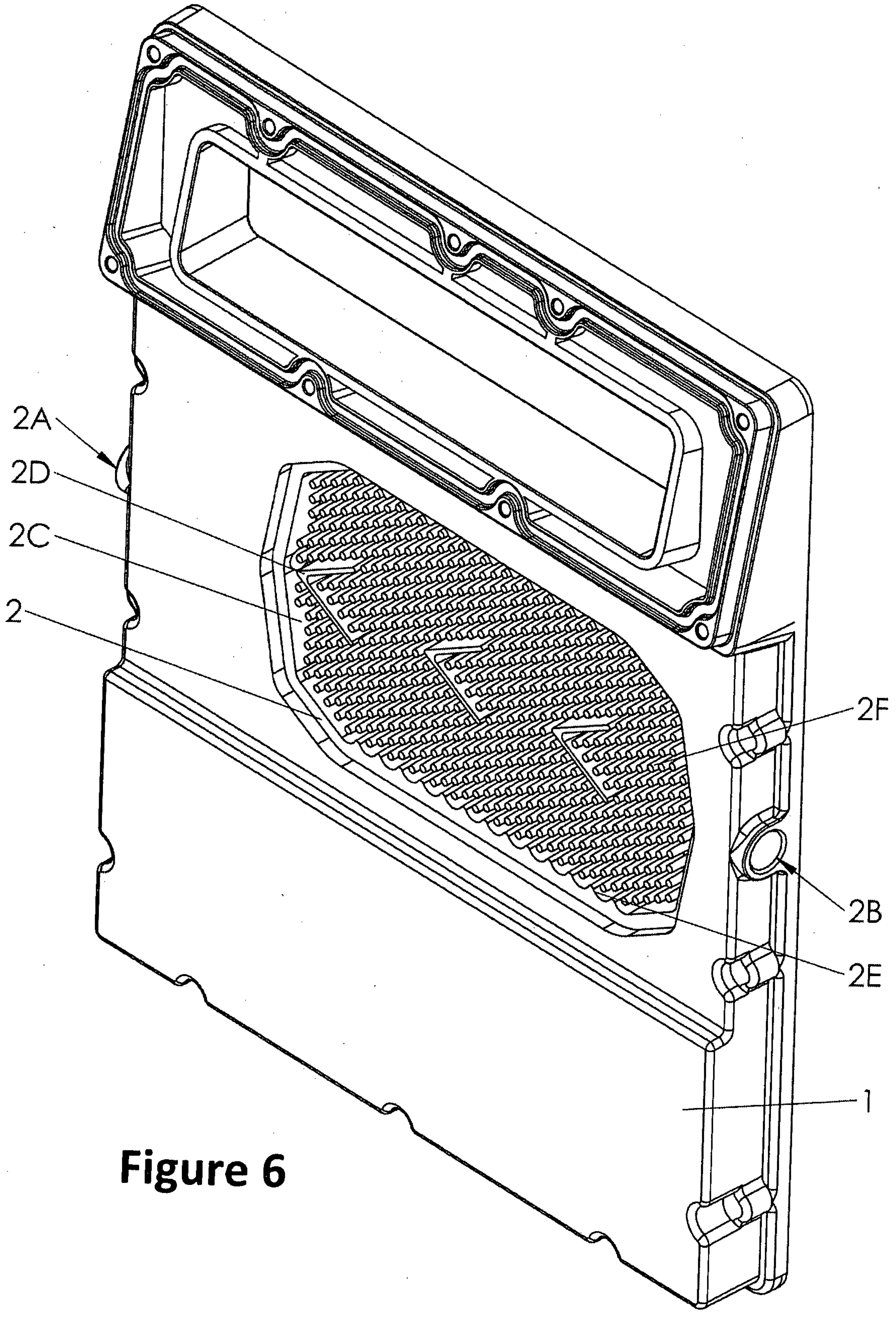

Figure 6

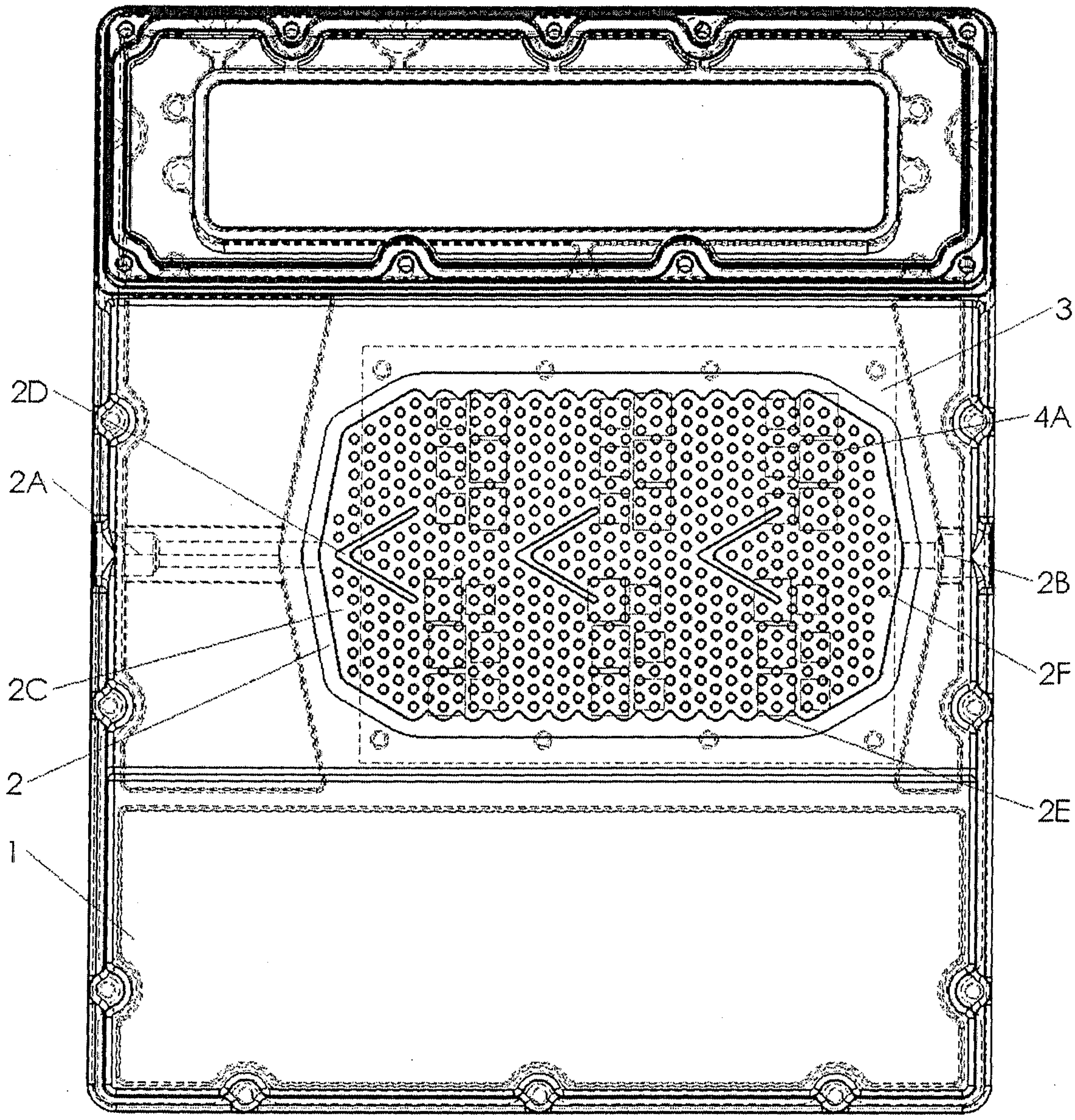

Figure 7

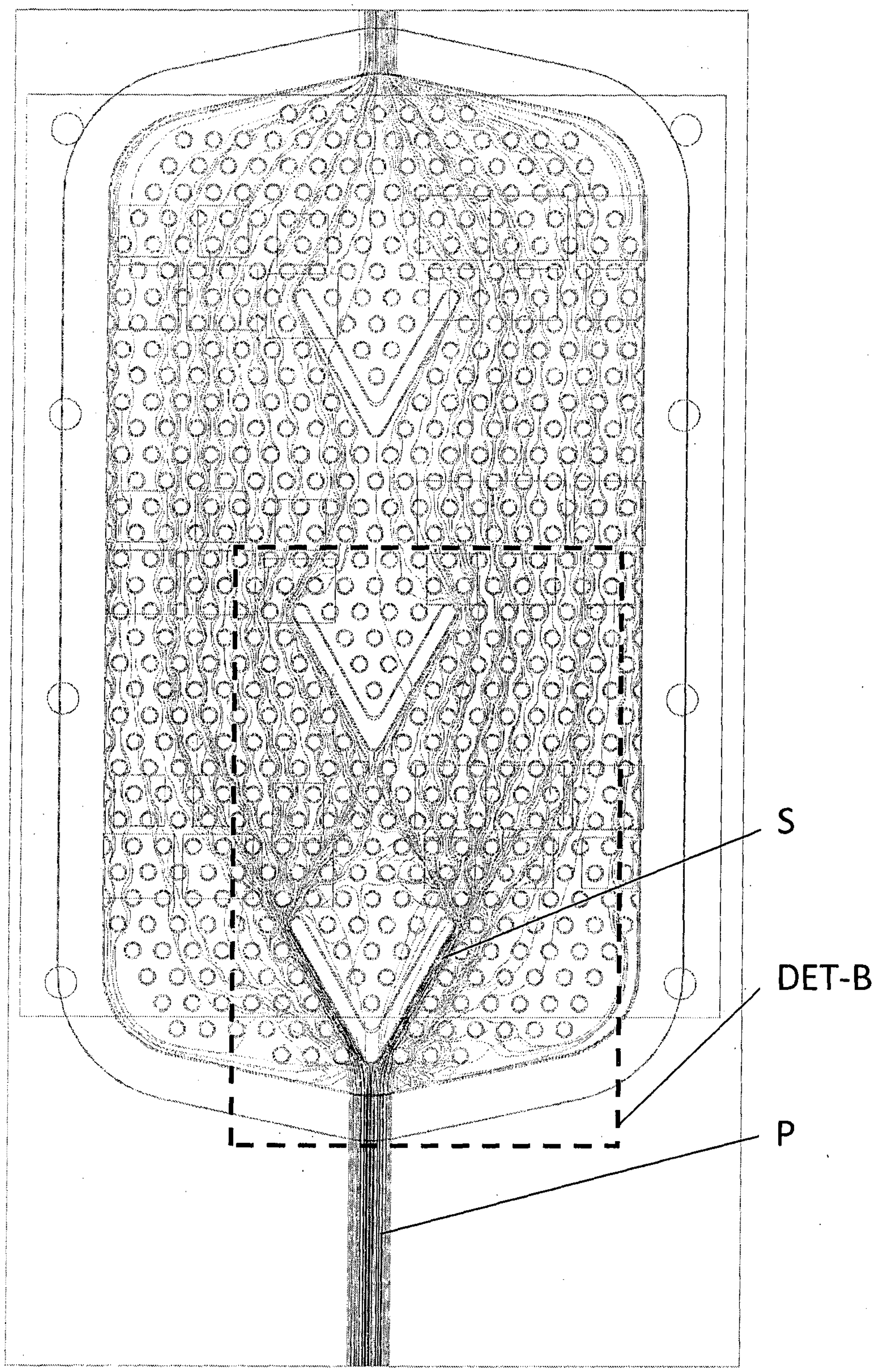

Figure 8

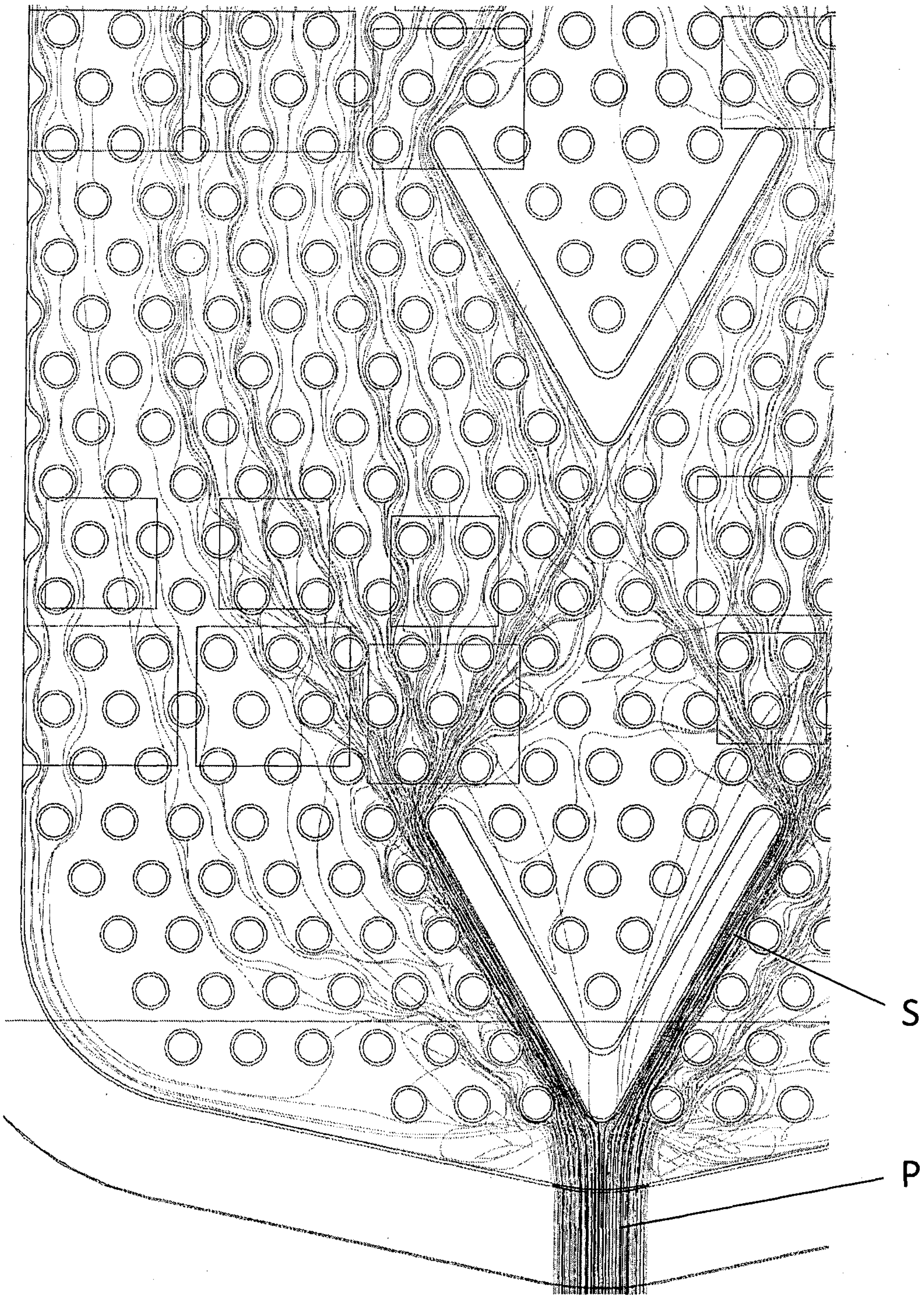

Figure 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/SI2012/000065

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L23/367 H01L23/473 F28F3/02 F28F3/12 F28F13/06
ADD.

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)
H01L F28F

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2012/114475 A1 (TOYOTA MOTOR CO LTD [JP]; TAKANO YUYA [JP]) 30 August 2012 (2012-08-30) abstract; figure 3 -----	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
22 August 2013	29/08/2013

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SI2012/000065

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012114475 A1	30-08-2012	JP 5051322 B1	17-10-2012
		WO 2012114475 A1	30-08-2012