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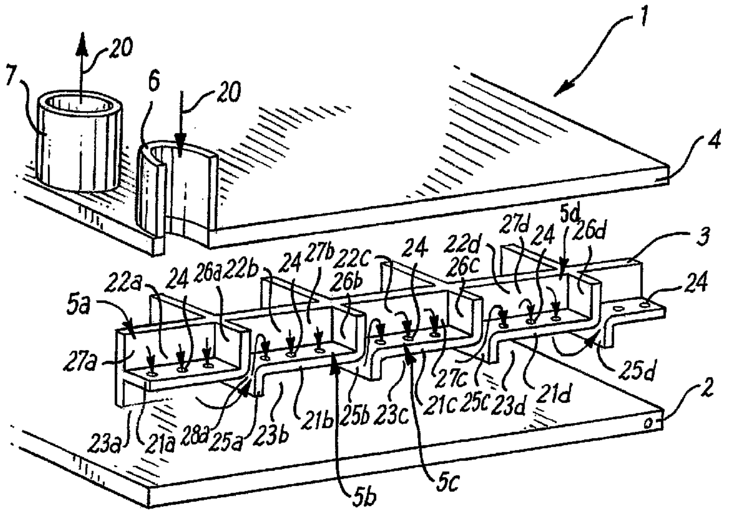
(54) Title: A COOLING ARRANGEMENT



(57) Abstract: A cooling arrangement (1) is provided in which a matrix (3) is arranged to provide a cascade path incorporating chambers (5) such that spent coolant which has impinged a target surface for cooling does not create a detrimental cross flow inhibiting subsequent down stream coolant jet impingement for cooling effect. The cascade path incorporates a permeable surface to divide a gallery portion and a cellar portion of each chamber (5) such that coolant flow passes through typically aperture jets in the permeable surface to become incident upon a target surface of a chassis (2), and the spent coolant is then collected within the cellar portion such that it flows through an outlet chimney slot formed between walls (25, 26). The coolant flow achieves a stepped flow elevation between successive chambers (5) in the cascade path for repeated jet impingement towards a target surface of the chassis (2).

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A Cooling Arrangement

The present invention relates to cooling arrangements for electronic components and more particularly for electronic components incorporated as electrical power control devices with respect to gas turbine engines.

The application of power electronics offers considerable opportunities to enhance the performance of an engine. Projected benefits of electronically optimised engines include improved functionality, reliability and maintainability along with reduced size, weight and fuel consumption. Due to the rapidly growing technical demand on power electronic devices, it is envisaged that the heat flux generated from the power electronic devices will increase from a current average of about ~100W/cm^2 to approximately ~1000W/cm^2 over the next ten years. Heat dissipation has therefore become a major concern for future development of power electronic devices.

In view of the above, it is desirable to provide improved cooling arrangements. One approach to achieving a cooling effect is through liquid jet impingement. In such systems a coolant jet is projected towards electronic components for cooling.

Jet impingement has excellent heat transfer characteristics. Typically, coolant jet impingement devices involve arrays of jets from which the spent coolant fluid exhausts in a single direction. In a jet array, the spent coolant fluid exhausted from the upstream jets forms a cross-flow that deflects the downstream impinging jets. An excessive cross-flow causes the downstream jets to be swept away limiting or even preventing impingement upon the target surface. As a result, the downstream jets produce lower heat transfer rates creating temperature gradients which may lead to some electronic components being inadequately cooled.

Generally, the electric components will be secured upon some form of chassis with the electronic components on one side and the coolant jet impingement on the other. In such circumstances, and as will be appreciated, some electronic components are subject to greater heating than others, thus it will be understood that different parts of the chassis may require different levels of cooling to be effective. Although the chassis inherently will distribute heat, that distribution in itself may heat components which would otherwise remain within acceptable operational temperature parameters. In such circumstances coolant fluid jet impingement as indicated above is complicated not only by the potential for downstream cross-flow inhibiting jet impingement on the target area of the chassis and components, but also by variations in localised heat generation by those components which ideally should be mirrored by the cooling arrangement.

In accordance with the present invention there is provided a cooling arrangement for electronic components, the arrangement comprising a chassis for electronic components, a matrix for a coolant flow and means to provide a coolant flow to the matrix, the matrix comprising a number of chambers arranged in a cascade path comprising a permeable surface and an outlet to a subsequent permeable surface, the permeable surface arranged to present coolant flow to the chassis whilst the outlet includes a stepped flow elevation to a subsequent permeable surface in the cascade path for limiting cross-flow impingement upon the coolant flow presented to the chassis.

Normally, limiting cross flow impingement forces elevation of the coolant flow to a subsequent chamber.

Generally, the coolant flow is presented to the chassis as a direct jet. Typically, the direct jet will be presented in a substantially perpendicular relationship to the chassis.

Normally, the matrix is a layer between the chassis or mounting plate and a coolant flow coupling member.

Generally, the matrix comprises chambers divided by the permeable surface into a gallery portion and a cellar portion. Normally, the outlet is directly coupled to the gallery portion incorporating the subsequent permeable surface.

Typically, the outlet comprises a chimney formed to one side of the subsequent permeable surface. Normally, the chimney includes an upstanding wall portion of the cellar portion associated with the subsequent permeable surface and an end wall of the gallery portion in a spaced staggered relationship.

Possibly, the matrix has a single cascade path. Alternatively, the matrix incorporates a plurality of cascade paths.

Possibly, the chambers and/or permeable surfaces are of different size for differing cooling effect and different parts of the matrix and/or cascade path relative to the chassis.

Generally, the permeable surface is perforated with jet apertures. Possibly, the jet apertures are distributed for cooling effect in terms of varying presentation of coolant flow to the chassis.

Also, in accordance with the present invention there is provided a coolant matrix comprising a number of chambers arranged in a cascade path comprising a permeable surface and an outlet to a subsequent permeable surface, the permeable surface arranged in use to present coolant flow to a chassis for electronic components whilst the outlet includes a stepped flow elevation to subsequent permeable surface for limiting cross-flow of coolant in use between chambers. Thus, the matrix can be tailored to specific performance requirements.

Further in accordance with the present invention there is provided a cooling arrangement for electronic components, the arrangement comprising a chassis for electronic components, a matrix for a coolant flow and means to provide a coolant flow to the matrix, the matrix comprising a number of chambers arranged in close association and each chamber comprising a plurality of impingement apertures to form a permeable surface, the impingement apertures arranged to present the coolant flow to the chassis whilst the outlet includes a step flow elevation to a subsequent permeable surface in the cascade path for limiting cross flow impingement upon the coolant flow to be entered to the chassis.

Additionally in accordance with the present invention there is provided a cooling arrangement for electronic components, the arrangement comprising a chassis for electronic components, a matrix for coolant flow and means to provide a coolant flow to the matrix, the matrix comprising a plurality of chambers arranged in a flow series, each chamber having a perforated member or permeable surface including a plurality of apertures arranged to direct a plurality of jets of coolant onto a surface of the chassis, each chamber having an inlet to receive the coolant flow and an outlet to discharge the coolant flow, the inlets of all but one chamber being supplied with coolant discharged from an immediately preceding chamber in the flow series, the chambers being packed closely together over the whole of the surface of the chassis and the apertures in the perforated member in each chamber being closely associated together over the whole of the surface of the chassis and the apertures in the perforated member in each chamber being packed closely together to provide uniform cooling of the chassis.

Preferably, the packing density of the apertures in each permeable surface is such that the pitch to diameter ratio of the apertures is in the range of 1.04 to 25.00.

Generally, the apertures in the permeable surface are arranged in regular rows and columns. Additionally, the apertures may be arranged in alternate rows and columns. Additionally, the apertures in adjacent rows are aligned in the same columns.

Typically the apertures have a diameter in the range of 0.1 to 6 mm. Advantageously, the apertures have a diameter of 0.1 mm to 3 mm.

Generally, limiting of cross flow of the coolant between the chambers creates a flow head upon the permeable surface. Normally, the permeable surface is a perforated surface with apertures in a desired distribution.

The permeable surface may be flat or curved or cylindrical.

Where the permeable surface is curved or cylindrical the cascade path may be generally radial or longitudinal along or around the permeable surface.

Embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings in which;

Fig. 1 is an exploded illustration of the components of a cooling arrangement in accordance with the present invention;

Fig. 2 is a front perspective view illustrating a cross section of a coolant arrangement as depicted in Fig. 1 in the plane X-X through an inlet;

Fig. 3 illustrates a matrix in accordance with the present invention;

Fig. 4 illustrates a matrix with a single cascade path in accordance with the present invention;

Fig. 5 is a plan view of a matrix in accordance with the present invention with multiple cascade paths;

Fig. 6 illustrates a first embodiment of a cylindrical cooling arrangement in accordance with the present invention;

Fig. 7 is a schematic illustration of a second embodiment of a cylindrical cooling arrangement in accordance with the present invention;

Fig. 8 is a schematic plan view depicting different arrangements of apertures in accordance with the present invention; and

Fig. 9 is a graphical representation of cooling effectiveness in terms of convective resistance to flow rate.

As indicated above, jet impingement upon a target surface provides good cooling effect if problems with respect to upstream impingement by cross flow upon downstream jet apertures can be avoided. In accordance with the present invention a matrix is provided in which chambers divide or corral the coolant jet impingement to particular parts of a chassis upon which electronic components are directly secured or associated through some form of heat transfer mechanism. In such circumstances, the benefits of coolant jet impingement are maintained without problems of free ranging cross flows as a result of unregulated coolant jet impingement.

Referring to Fig. 1, as can be seen a coolant arrangement 1 comprises a chassis plate 2, a matrix 3 and a coolant flow coupling plate 4. In Fig. 1 the components 2, 3, 4 are shown in an exploded view but normally as will be understood these components form a sandwich with the matrix 3 between the chassis 2 and the coupling plate 4. In such circumstances a number of chambers 5 are closed at each side by the chassis 2 and coupling plate 4 respectively, but in accordance with the present invention, each chamber 5 incorporates an outlet to subsequent chambers in a cascade path. A coolant fluid enters the arrangement 1 through an input duct 6 which is coupled to a first chamber or a distribution manifold for cascade paths incorporated in the matrix 3. The coolant flow passes through the chambers of each cascade path such that coolant flow passes through a permeable surface in each chamber for jet impingement upon one side of the chassis 2.

It should be understood that the permeable surface in accordance with the present cooling arrangement generally comprises a densely packed number of holes or apertures with a pitch to diameter ratio range in the order of 1.04 to 25. Thus, the apertures acting as jet nozzles for coolant flow are densely packed. These holes or apertures are all in rows and the rows may be offset relative to each other as described later with regard to Fig. 8.

As indicated above, the chassis 2 will be associated with electronic components either through those components being directly secured upon the chassis 2, on an opposite side to that of the coolant jet impingement or the target area part of the chassis 2 subject to coolant jet impingement will be coupled through an appropriate heat transfer mechanism to electronic component mounting structures, etc. Furthermore, there may be an intermediate mounting plate, containing electric components (heat source) on one side and impingement coolers on the other. In any event, heat energy will generally be presented to one side of the chassis as indicated by arrowheads 8. The chassis 2 and mounting plate (optional extra feature) will be made from a thermally conductive material such that the coolant jet impingement on the other side of the chassis 2 will cool that chassis 2 despite the heat energy presented in the direction of arrowheads 8.

Fig. 2 illustrates a front perspective view of a cross section through a plane bisecting the inlet duct 6 in Fig. 1 (Plane X-X). Thus, as can be seen the chassis 2 is associated with the matrix 3 with a coolant flow coupling plate 4 for the input duct 6 presenting a coolant fluid flow, typically air, in the direction of arrowhead 20 to a first chamber 5a and this chamber 5a in association with subsequent chambers (both those shown and subsequent chambers act to form a cascade path from that input duct 6 to the output duct 7). In such circumstances the cooling arrangement 1 provides cooling of the chassis 2 which as indicated previously will be either directly or otherwise associated with electronic components which require cooling. Each chamber 5 is divided by a permeable surface 21 into a gallery portion 22 and a cellar portion 23. In the embodiment depicted this permeable surface 21 incorporates apertures 24 or perforations such that the coolant flow is jetted through those apertures 24 for impingement upon a surface of the chassis 2. Normally, such impingement will be such that there is perpendicular presentation of the coolant jets towards the surface of the chassis 2. However, where desired the coolant flow impingement in the form of directed flow may be angled towards its target surface of the chassis 2.

As indicated above, in accordance with the present invention the target surface of the chassis 2 is divided by the respective chambers 5 to limit the effects of downstream cross flow. Thus, in accordance with the present invention the coolant flow passing through the permeable surface 21 impinges upon the target surface of the chassis 2 and then is constrained by walls upon three sides and a spaced upstanding wall portion 25 of a cellar portion 23 in a subsequent chamber 5 of the cascade path. This upstanding wall portion 25 is spaced from an end wall 26 of the previous chamber 5 in order to create a staggered chimney 28 through which the coolant flow passes, such that there is an effective stepped flow elevation to a subsequent permeable surface 21 in the next chamber 5. In the embodiment depicted in Fig. 2 it will therefore be understood that a coolant flow passes through the input duct 6 to enter the first chamber 5a and in particular its gallery portion 22a. Thus through a pressure differential this coolant flow passes through the apertures 24 in the permeable surface 21 of the first chamber 5a in order to impinge upon the surface of the chassis 2 which forms part of the cellar portion 23a of the first chamber 5a. Once the coolant jet has impinged upon the target area of the chassis 2 for the first chamber 5a, its only route for escape is through an outlet formed by the chimney 28 defined between a wall portion 25 of the cellar portion 23b of a subsequent chamber 5b and a wall portion 26 of the gallery portion 22a of the first chamber 5a. The coolant flow is thereby step elevated into the gallery portion 22b of the chamber 5b and again through pressure differential passes through the apertures 24 into the cellar portion 23b of the chamber 5b again through impingement upon a differing target area of the chassis 2 for cooling effect. This process is repeated throughout the cascade path formed by the chambers 5 until the coolant exits from the arrangement 1 through the output duct 7.

A further consequence of density packing of apertures is that there is a requirement for a maximum of two O ring seals, one on each side of the matrix 3 plate as depicted in Fig. 2. Previously it was a requirement to provide a number of O ring seals dependent upon the number of cascading chambers. It will be understood that with such multiple O ring seal arrangements there are time intensive manufacturing and assembly difficulties, more possibly of leakage through the O ring seals, and a general increase in cost as a result of manufacturing assembly.

A further consequence of the present arrangement is that the effective flow from the jets building up in the direction of outlet is utilised to act as a cross flow which is collected through an outlet after a limited number of rows of aperture jets. This cross flow is then fed to a new plenum and feeds a new set of jets. In such circumstances the cross flow then builds up again in the new plenum until it is collected and acts as a flow head to feed a further plenum with a cascade. This means of collecting the flow and feeding similar cooling geometries can be considered as cascade through the arrangement facilitating cooling effect.

The upstanding wall portion 25 prevents cross flow affecting the coolant flow presented through the apertures 24 of the second chamber 5b, and so more effective coolant flow impingement will occur. Nevertheless, it will be understood that essentially each subsequent chamber 5 of a cascade path receives increasingly warmed coolant flow from its previous chamber 5, and so consideration must be made as to any variation in relative chamber 5 size and/or permeable surface 21 and/or the path length of the cascade path formed by the chambers.

Fig. 3 provides a front perspective view of a matrix 3 utilised in accordance with the present invention. As can be seen, each chamber 5 is substantially rectangular and includes a relatively even spread of apertures for impingement flow upon the chassis as described previously. However, it will also be understood that where desired differing aperture distributions and/or dimensions and/or numbers may be provided for varying coolant flow impingement in order to accommodate for differing cooling requirements. Nevertheless, it will be understood that each chamber 5 incorporates an outlet chimney as described previously between adjacent chambers 5 in order to create in use the desired stepped flow elevation in a coolant flow between subsequent chambers 5 to avoid cross flow diminishing of coolant flow impingement as well as to create a head for directing coolant flow impingement jetting upon the chassis surface (not shown).

By using the present invention, uncontrolled and excessive cross flow by cascading the exhaust fluid into downstream jet array chambers 5 is avoided. This enhances and optimises each coolant liquid impingement heat transfer on the target surface of the chassis 2. In addition, the cascading of the jet impingement apertures allows the exhausted coolant fluid to exit to the chamber 5b. This considerably reduces the amount of coolant required (e.g. fuel or water) to dissipate a particular heat load 8 upon the chassis 2.

As indicated above, chambers 5 in accordance with the present invention form a cascade path through which a coolant flow passes such that there is repeated coolant flow impingement upon chamber defined target segments of the chassis surface. Figs. 4 and 5 illustrate alternative approaches to achieving best cooling effect. In Fig. 4 a plan view of a single cascade path is illustrated. Thus, a matrix 43 has an input duct 41 and an output duct 42 such that a coolant flow as indicated by arrowhead 40, passes from an input duct 41 through a succession of chambers 45 incorporating a permeable surface and outlet chimney between a gallery portion of those chambers 45 and a cellar portion. In such circumstances, and as indicated above, the coolant flow 40 will gradually become hotter and hotter as it passes through the chambers 45 until exiting through an output duct 42. In such circumstances, care must be taken with respect to the actual distribution and size of the chambers 45 along with permeable surface dimensions in order to achieve appropriate cooling in the desired different portions of an impinged chassis surface subject to heating through electronic components. Nevertheless, as the coolant flow 40 is essentially corralled in each cellar portion, as described previously, there is little cross flow diminution in coolant jet impingement such that cooling efficiency will be significantly greater than for a simple flat plate impingement regime typical with previous arrangements.

Fig. 5 illustrates a plan view of a multi cascade path embodiment of the present invention. Thus, a matrix 53 has an input duct 51 and an output duct 52 such that a coolant flow depicted by arrowheads 50 can pass through three different cascade paths 50a, 50b, 50c between the input duct 51 and the output duct 52. In the schematic depiction shown in Fig. 5 the chamber walls are not depicted but each divided chamber is shown by its aperture distribution pattern, and it will be understood that the coolant flows 50a, 50b, 50c will each pass through chambers (not shown) such that there is common jet impingement through the permeable surfaces 54 upon a chassis surface and that subsequently the coolant flow 50 will pass through a chimney outlet for stepped elevation to a subsequent permeable surface 54 such that there is no cross flow diminution between surfaces 54 in terms of cooling jet impingement upon its respective target area of the chassis for cooling effect.

Returning to Figs. 2 and 3, it will be seen that the chassis 2 can be a mounting surface for spreading heat of mounted electric components (electric heat loss and/or switching losses) aperture jets are arranged specifically for impingement upon a surface of the chassis 2. Each permeable surface 21a, 21b, 21c is confined within a chamber 5a, 5b, 5c which is formed by four confinement walls 26a, 27a, 26b, 27b, 26c, 27c on the gallery portion 22a, 22b, 22c of the chamber 5a, 5b, 5c. From the input port 6, liquid coolant is pressurised to flow through the first apertures 24a of the permeable surface 21a. Possibly, there is an 4 x 4 aperture jet pattern or a 5 x 5 aperture jet pattern, but this will depend upon particular operational requirements, etc. Following coolant jet impingement on a hot target surface of the chassis 2 below the first chamber 5a, spent coolant flow is collected in the cellar portion 23a of the chamber 5a and, via a chimney 28a outlet slot fed to the next apertures 24b of the permeable surface 21b in the subsequent chamber 5b. The walls 25, 26 are arranged to guide the coolant flow between permeable surfaces 21 to create the desired jet impingement upon the target surface of the chassis 2. The coolant flows through the impingement apertures 24 at each chamber 5 and strikes a respective hot target surface of the chassis 2 before cascading into the next chamber. The jet impingement process carries on in the subsequent chambers 5 with an appropriate use of an outlet chimney 28 slot to divert, sometimes at right angles to the upstream slot direction the coolant flow in its respective cascade path. The liquid coolant exits the arrangement 1 via the last chamber 5 in the cascade path and the output port 7.

Flexibility is provided in available arrangements in accordance with the present invention by having a single cascade path or a multiple cascade path alternative through respective arrangements to enable a balance to be struck between the required coolant flow rate and the resulting pressure drop through the arrangement to be chosen for particular cooling requirements.

As the coolant temperature gradually increases through the arrangement, the build up of a temperature gradient can be detrimental to particular power electronic devices. To alleviate this temperature build up the specific cascade route for the coolant flow through the arrangement can be selected such that the first inlet chamber and the last chamber as depicted in Fig. 4 are situated near to each other to maximise the temperature uniformity across the chassis and therefore relative to electronic devices secured to that chassis. Alternatively, as depicted in Fig. 5, cascade paths can provide a tailored feed coolant flow in different streams through an arrangement in accordance with the present invention.

The present impingement jet cooling arrangement provides high cooling capacity and is also compatible with existing commercially available power electronic modules in terms of allowing those modules to be secured to one side of a chassis 2 in accordance with the invention. The coolant jet impingement created by the permeable surface can be directed onto a specific target area of the chassis, and that target area may itself be associated with a particular power electronic device, without modification to either the chassis or the electronic device. The structure of the present arrangement can be sufficiently compliant such that thermal expansion of associated electronic devices can be accommodated without associated increases in arrangement stresses. The liquid impingement arrangement in accordance with the present invention can also be modified according to localised cooling requirements, particularly in respect of areas or spots of high heat density beneath particular power electronic devices. This modification can be achieved by selective choice of chamber size and position along with permeable surface in terms of aperture jet distribution and size. As indicated above, an alternative is an intermediate mounting plate for the electronic components.

Alterations and variations of the described embodiment above can be envisaged particularly with respect to the permeable surface in terms of jet aperture shape, length and distribution in order to achieve the desired coolant jet impingement upon a target surface for cooling of that surface. It will also be understood that the chambers as an alternative to being rectangular or square as described and illustrated above may be themselves shaped in terms of their plan cross section as well as doming or other features in order to achieve the desired pressure differential for coolant jet impingement upon a target surface in a chassis associated with devices to be cooled. The aperture may be circular and have a diameter in the range 01.mm to 6mm, more preferably 0.1mm to 3mm, preferably 0.2mm to 1mm. If apertures with other shapes are used then their dimensions are selected to provide the equivalent cross-sectional areas.

Figs. 6 and 7 provide illustrations of use of a cylindrical chassis rather than a flat chassis in previous embodiments described above. Thus, in Fig. 6 there is a schematic illustration in which Fig. 6a is of an end view of a cylindrical chassis and in Fig. 6b there is a side perspective view of a cylindrical chassis in accordance with a first embodiment of a cylindrical cooling arrangement in accordance with the present invention. Fig. 7 provides a schematic side view of a second embodiment of a cylindrical cooling arrangement in accordance with the present invention in which Fig. 7a is a side view and Fig. 7b a cross section in the plane A-A of the arrangement shown in Fig. 7a.

It is essentially the cascade effect of coolant flow over the chassis which is utilised in order to enhance cooling effect. Thus, as depicted in Fig. 6 an inlet 61 for coolant flow arranges to couple coolant flow to a first plenum chamber 63 which includes a perforated surface 64 generally in a lower part 63a which acts as a cellar portion. Thus, if the cylindrical chassis is enclosed it will be understood in a similar fashion to that described previously, coolant flow in the direction of the arrowheads depicted in Fig. 6 will enter the plenum chambers 63 and pass through those chambers via a chimney elevation portion 65 between each plenum chamber. In the embodiment depicted in Fig. 6 it will be understood that the coolant flow is essentially radial around the four plenum chambers depicted as 63a, 63b, 63c, 63d along the length of the cylindrical chassis until it exits through outlet 62. In such circumstances as described previously there is cascade flow between the various chambers 63 incorporating the cellar portion 63 a-d with coolant effect emphasised by the movement through the cellar portions and intervening chimney portions 65 in accordance with the regime described previously. The apertures as also described previously are generally closely packed and of a size ratio sufficient to create the cross flow head for stimulating coolant flow through the chambers including the cellar portions 63. In such circumstances a hot surface of the central cylinder 60 will be cooled by the coolant flow indicated by the arrowheads.

Fig. 7 illustrates a second embodiment of a cylindrical chassis in accordance with the present invention. In this second embodiment, coolant flow is longitudinal along the length of the cylindrical chassis 70 rather than as a generally circumferential flow as depicted in the first embodiment of a cylindrical chassis cooling arrangement in accordance with that depicted and described with regard to Fig. 6. In this second embodiment coolant flow is depicted again by the arrowheads and is generally from an inlet 71 to an outlet 72. Again the cylinder will generally be surrounded by a sleeve (not shown) in order to create the chambers with a perforated surface 74 below which a cellar portion 73 is formed in order to create a cross flow head such that a chimney portion 75 acts to create a cascade between the perforated surfaces 74a, 74b, 74c to the outlet 72. As can be seen in Fig. 7b taken in the plane A-A of Fig. 7a, a cellar portion 73 is created through which there is coolant flow and subsequently through the elevation created by the chimney portion 75a (not shown in Fig. 7b). Coolant flow head is created to stimulate close association with the cylinder 70 and therefore enhance cooling performance.

In short, it can be appreciated that the difference between the embodiments of a cylindrical chassis coolant depicted in Fig. 6 and 7 there is a general radial flow circumferentially around the cylinder Fig. 6, whilst there is a general longitudinal flow in the embodiment depicted in Fig. 7.

As with all the embodiments described above the aperture hole arrangements in the perforated surface can be arranged in a geometric pattern. Typically that pattern will comprise rows and columns in two perpendicular directions. These patterns may be regular or the arrangement can be offset in staggered rows if necessary, that is to say one aperture of an adjacent row is not aligned with the aperture in the previous row. Alternatively, other patterns or random geometries or aperture holes can be used dependent upon operational requirements.

In addition to the aperture holes being circular, it will be appreciated that the holes may be rectangular, oval, triangular and any other polygon or angular shape dependent upon flow effect in order to achieve the desired cooling efficiency.

The perforated surface in which the apertures are included can be presented as described above generally in a parallel form to the surface to be cooled by impingement of the coolant flow or alternatively the perforated surface can be at an angle to the impinged surface or flat relative to a curved impinged surface dependent upon requirements. Thus, for example in the cylindrical embodiments described with regard to Fig. 6 and 7, the perforated surface 64, 74 may be arranged to have a different circumference to the underlying cylinder 60, 70 or be offset so that there is a greater spacing between the surfaces 64, 74 and the cylinder 60, 70 to one side in comparison with the other side.

Generally the matrix of cooling arrangement in accordance with the present invention will be formed from any suitable material including metal, but also may be injection moulded plastic material. Furthermore, it will be understood that the coolant flow may be gaseous in the form of air or liquid flows for example kerosene, oil, diesel, petrol, water, alcohol or glycol/water mixes may be used as the coolant flow.

The present cooling arrangement may be used with regard to a range of environments such as marine and ships, spacecraft and aircraft, automotive and traction, computer and electrical equipment, cooling of general instrumentation and cooling of conventional heat spreader plates to distribute heat loading a standard electronic component apparatus.

As indicated above generally the aperture distribution will be relatively densely packed. The pitch to diameter ratio of the apertures will generally be in the range 1.04 to 25. For consistency it will be appreciated that normally the apertures will be arranged in regular rows and columns with a dense packing for uniform cooling. The pitch of the arrangement will be the distance between the centres of the apertures in the perforated surface. Generally the diameters of the apertures as well as their specific distribution and the number of holes will be determined by careful analysis as to the particular operational requirements for heat dissipation.

For flow control it will be appreciated that generally within normal constraints the objective will be to maximise a number of perforations in the perforated surface. Generally, each chamber including a cellar portion and the perforated surface will provide some cooling on an iterative basis with regard to the whole arrangement. The chambers may be square or any other shape. Furthermore, chambers may be adjusted in size and shape in order to create turns in coolant flow. In order to create the cross flow, generally the area of the chimney portions will be arranged to be equal roughly to all the holes/apertures in the preceding perforated surface plus or minus 20%. Generally there is an objective to maximise the capacity for cooling whilst minimising detrimental features such as the complexities with regard to inclusion of O ring seals which are difficult to assemble and may increase the potential for leakage between chambers.

Fig. 8 illustrates with regard to Fig. 8a, a potential offset distribution of columns and rows of apertures 88 in an aperture surface 84, whilst in Fig. 8b a regular distribution of apertures 99 in a perforated surface 94 is depicted. It will be understood that these illustrations only represent a small proportion of the perforated surface 84, 94. Additionally as indicated previously the actual distribution of the apertures 88, 99 will be determined by operational requirements.

Fig. 9 provides a graphic illustration of thermal resistance to flow rate. In such circumstances, as can be seen, there is a non linear relationship between thermal resistance and flow rate. It is this non-linearity which is utilised in order to create the cross flow stimulation in accordance with the present invention.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

CLAIMS

1. A cooling arrangement for electronic components, the arrangement comprising a chassis for electronic components, a matrix for a coolant flow and means to provide a coolant flow to the matrix, the matrix comprising a number of chambers arranged in a cascade path comprising a permeable surface and an outlet to a subsequent permeable surface, the permeable surface arranged to present coolant flow to the chassis whilst the outlet includes a stepped flow elevation to a subsequent permeable surface in the cascade path for limiting cross-flow impingement upon the coolant flow presented to the chassis.

2. An arrangement as claimed in claim 1 wherein the coolant flow is presented to the chassis as a direct jet.

3. An arrangement as claimed in claim 2 wherein the direct jet will be presented in a substantially perpendicular relationship to the chassis.

4. An arrangement as claimed in any of claims 1, 2 or 3 wherein the matrix is a layer between the chassis and a coolant flow coupling member.

5. An arrangement as claimed in any preceding claim wherein the matrix comprises chambers divided by the permeable surface into a gallery portion and a cellar portion.

6. An arrangement as claimed in claim 5 wherein the outlet is directly coupled to the gallery portion incorporating the subsequent permeable surface.

7. An arrangement as claimed in any preceding claim wherein the outlet comprises a chimney formed to one side of the subsequent permeable surface.

8. An arrangement as claimed in claim 7 wherein the chimney includes an upstanding wall portion of the cellar portion associated with the subsequent permeable surface and an end wall of the gallery portion in a spaced staggered relationship.

9. An arrangement as claimed in any preceding claim wherein the matrix has a single cascade path.

10. An arrangement as claimed in any of claims 1 to 8 wherein the matrix incorporates a plurality of cascade paths.

11. An arrangement as claimed in any preceding claim wherein the chambers and/or permeable surfaces are of different sizes for differing cooling effect and different parts of the matrix and/or cascade path relative to the chassis.

12. An arrangement as claimed in any preceding claim wherein the permeable surface is perforated with jet apertures.

13. An arrangement as claimed in claim 12 wherein the jet apertures are distributed for cooling effect in terms of varying presentation of coolant flow to the chassis.

14. A cooling arrangement for electronic components substantially as hereinbefore described with reference to the accompanying drawings.

15. A cooling arrangement for electronic components, the arrangement comprising a chassis for electronic components, a matrix for a coolant flow and means to provide a coolant flow to the matrix, the matrix comprising a number of chambers arranged in close association and each chamber comprising a plurality of impingement apertures to form a permeable surface, the impingement apertures arranged to present the coolant flow to the chassis whilst the outlet includes a step flow elevation to a subsequent permeable surface in the cascade path for limiting cross flow impingement upon the coolant flow to be entered to the chassis.

16. A cooling arrangement for electronic components, the arrangement comprising a chassis for electronic components, a matrix for coolant flow and means to provide a coolant flow to the matrix, the matrix comprising a plurality of chambers arranged in a flow series, each chamber having a perforated member

or permeable surface including a plurality of apertures arranged to direct a plurality of jets of coolant onto a surface of the chassis, each chamber having an inlet to receive the coolant flow and an outlet to discharge the coolant flow, the inlets of all but one chamber being supplied with coolant discharged from an immediately preceding chamber in the flow series, the chambers being packed closely together over the whole of the surface of the chassis and the apertures in the perforated member in each chamber being closely associated together over the whole of the surface of the chassis and the apertures in the perforated member in each chamber being packed closely together to provide uniform cooling of the chassis.

17. An arrangement as claimed in claim 12 and any claim dependent thereon or claim 15 or claim 16 wherein the packing density of the apertures in each permeable surface is such that the pitch to diameter ratio of the apertures is in the range of 1.04 to 25.00.

18. An arrangement as claimed in claim 12 or any claim dependent thereon or claims 15 to 17 wherein the apertures in the permeable surface are arranged in regular rows and columns.

19. An arrangement as claimed in claim 12 or any of claims 15 to 17 wherein the apertures may be arranged in alternate rows and columns.

20. An arrangement as claimed in claim 12 and any claim dependent thereon or claim 15 to 19 wherein the apertures in adjacent rows are aligned in the same columns.

21. An arrangement as claimed in claim 12 or any of claims 15 to 20 wherein the apertures have a diameter in the range of 0.1 to 6mm.

22. An arrangement as claimed in claim 21 which the apertures have a diameter in the range 0.1 to 3mm

23. An arrangement as claimed in claim 21 or claim 22 wherein the apertures have a diameter of 0.2mm to 1mm.

24. An arrangement as claimed in any preceding claim wherein limiting of cross flow of the coolant between the chambers creates a flow head upon the permeable surface.

25. An arrangement as claimed in any preceding claim wherein the permeable surface may be flat or curved or cylindrical.

26. An arrangement as claimed in any preceding claim wherein where the permeable surface is curved or cylindrical the cascade path may be generally radial or longitudinal along or around the permeable surface.

27. A coolant matrix comprising a number of chambers arranged in a cascade path comprising a permeable surface and an outlet to a subsequent permeable surface, the permeable surface arranged in use to present coolant flow to a chassis and/or mounting plate for electronic components whilst the outlet includes a stepped flow elevation to a subsequent permeable surface for limiting cross-flow of coolant in use between chambers.

28. A matrix as claimed in claim 27 wherein the matrix comprises chambers divided by the permeable surface into a gallery portion and a cellar portion.

29. A matrix as claimed in claim 28 wherein the outlet is directly coupled to the gallery portion incorporating the subsequent permeable surface.

30. A matrix as claimed in any of claims 27 to 29 wherein the outlet comprises a chimney formed to one side of the subsequent permeable surface.

31. A matrix as claimed in claim 30 wherein the chimney includes an upstanding wall portion of the cellar portion associated with the subsequent permeable surface and an end wall of the gallery portion in a spaced staggered relationship.

32. A matrix as claimed in any of claims 27 to 29 wherein the matrix has a single cascade path.

33. A matrix as claimed in any of claims 27 to 29 wherein the matrix incorporates a plurality of cascade paths.

34. A matrix as claimed in any of claims 27 to 33 wherein the permeable surface is perforated with jet apertures.

35. A matrix as claimed in claim 34 wherein the jet apertures are distributed for cooling effect in terms of varying presentation of coolant flow to the chassis.

36. A matrix as claimed in any of claims 27 to 35 wherein the matrix is an injection moulding.

37. A coolant matrix substantially as hereinbefore described with reference to the accompanying drawings.

38. Any novel subject matter or combination including novel subject matter disclosed herein, whether or not within the scope of or relating to the same invention as any of the preceding claims.

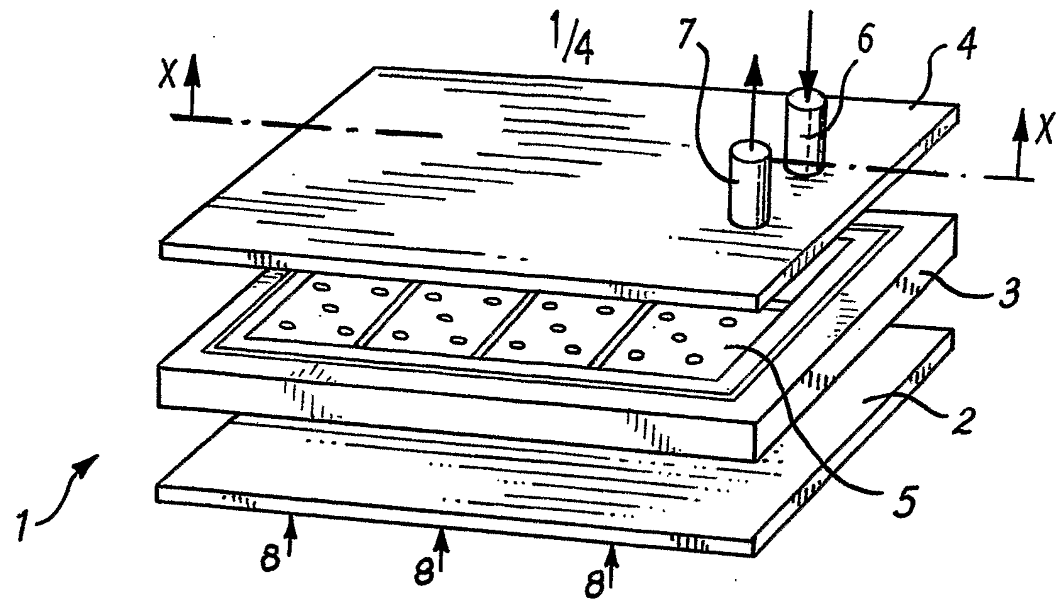
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FIG. 1

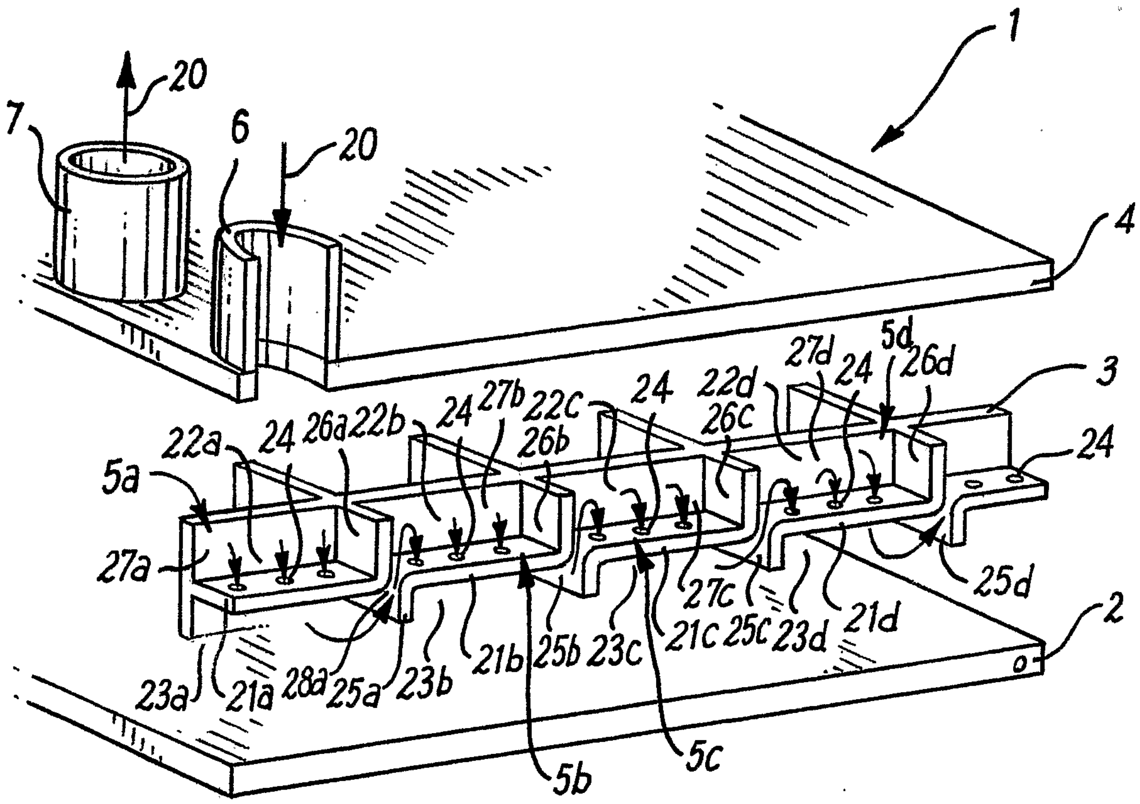
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FIG. 2

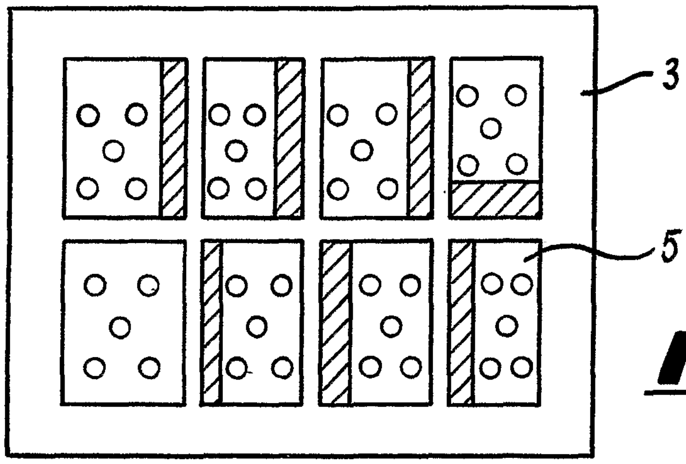

FIG. 3

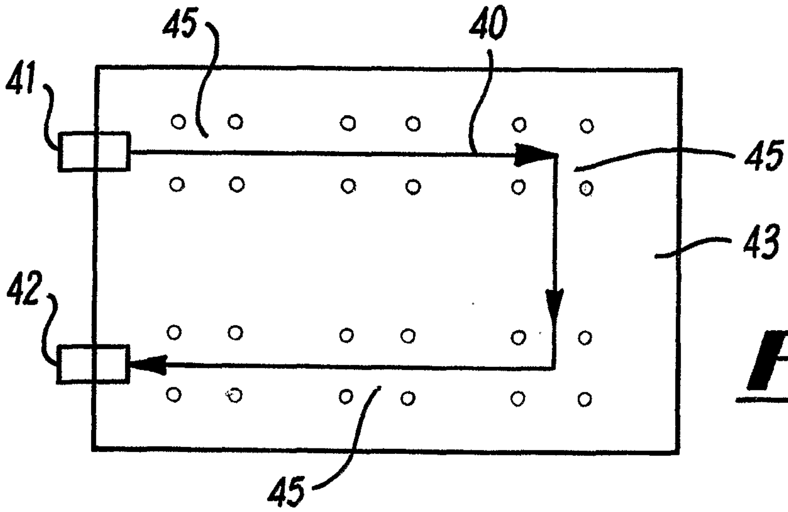

FIG. 4

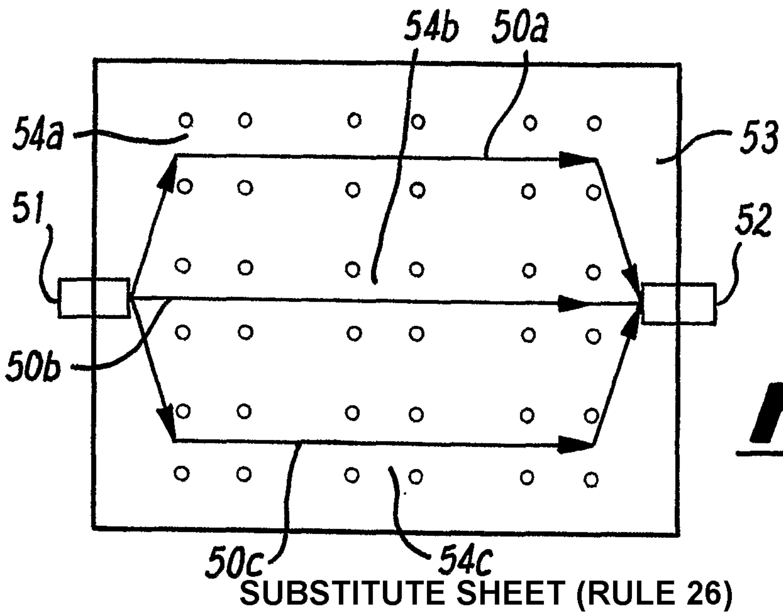

FIG. 5

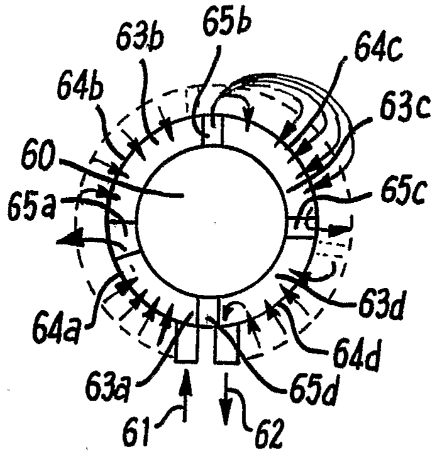

FIG. 6a

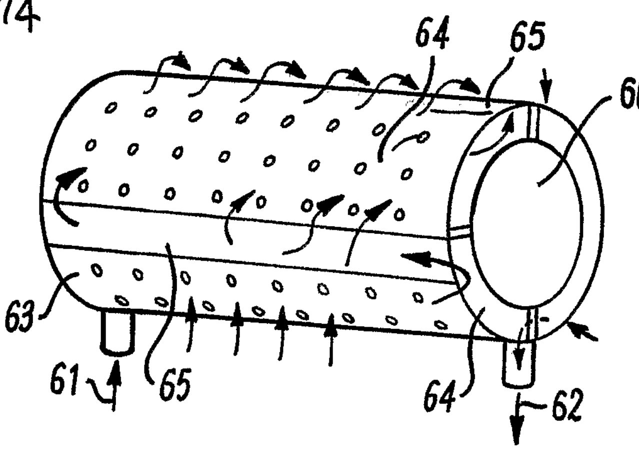

FIG. 6b

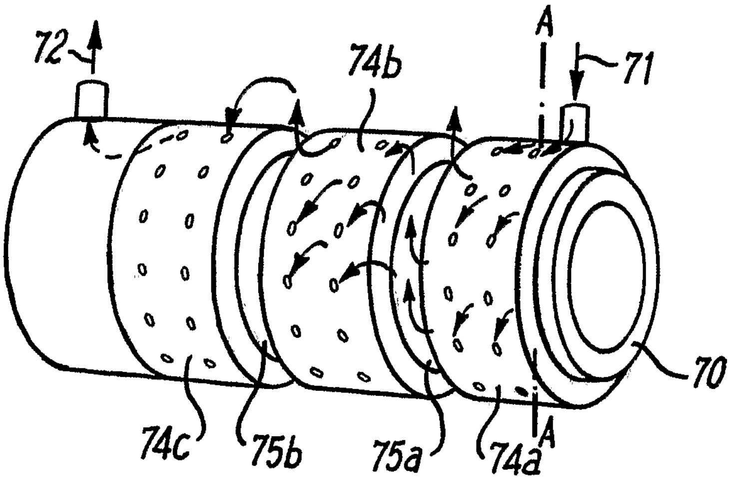

FIG. 7a

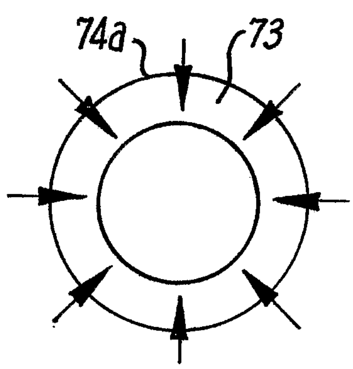

FIG. 7b

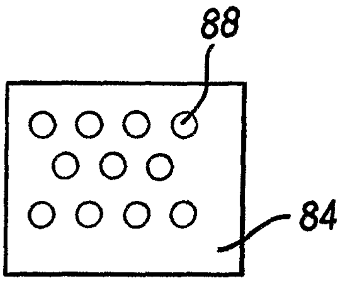

FIG. 8a

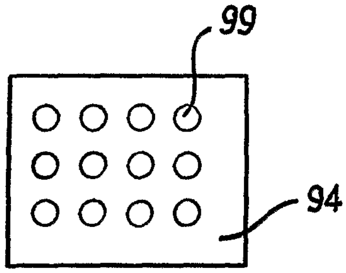

FIG. 8b

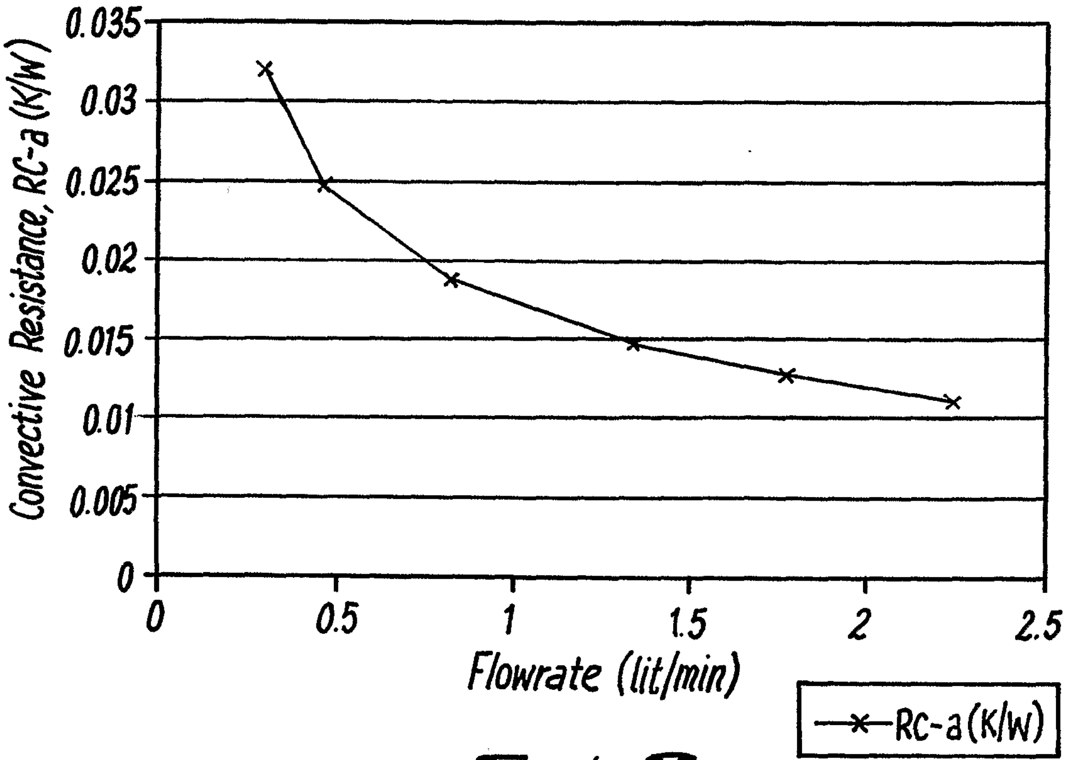

FIG. 9

INTERNATIONAL SEARCH REPORT

PCT/GB2005/002018

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L23/473

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 7 H05K H01L

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 841 634 A (VISSER ET AL) 24 November 1998 (1998-11-24) the whole document	1-38
A	DE 202 08 106 U1 (DANFOSS SILICON POWER GMBH) 10 October 2002 (2002-10-10) the whole document	1,15,16, 27
A	EP 1 283 550 A (KABUSHIKI KAISHA TOSHIBA) 12 February 2003 (2003-02-12) the whole document	1,15,16, 27
A	EP 0 516 478 A (NEC CORPORATION) 2 December 1992 (1992-12-02) the whole document	1,15,16, 27

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

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2005	15/09/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Toussaint, F

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

Information on patent family members

PCT/GB2005/002018

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