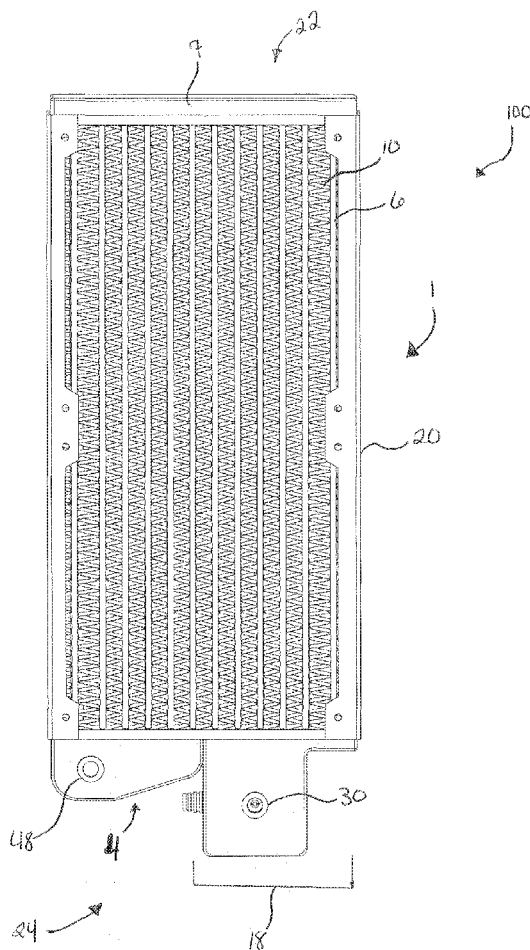


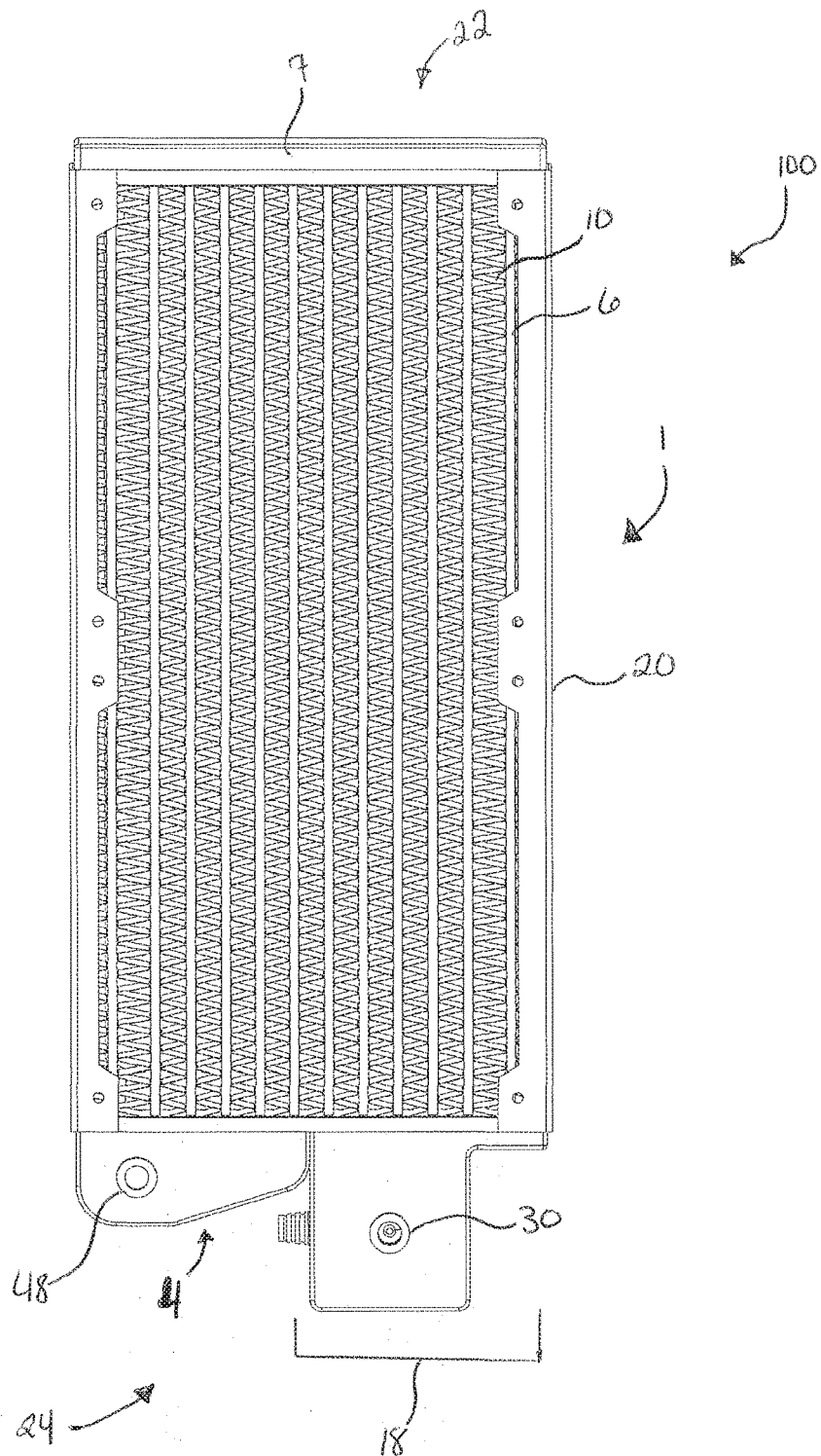


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Mounioloux(10) **Pub. No.: US 2018/0340736 A1**(43) **Pub. Date: Nov. 29, 2018**(54) **RADIATOR WITH INTEGRATED PUMP FOR
ACTIVELY COOLING ELECTRONIC
DEVICES***H01L 23/473* (2006.01)*F28D 21/00* (2006.01)(52) **U.S. Cl.**CPC *F28D 1/04* (2013.01); *F28D 1/05366*
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1/05341 (2013.01)(71) Applicant: **Rouchon Industries, Inc.**, Pico Rivera,
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(US)(21) Appl. No.: **16/052,886**(22) Filed: **Aug. 2, 2018****Related U.S. Application Data**(63) Continuation of application No. 12/969,284, filed on
Dec. 15, 2010, now Pat. No. 10,048,008.(60) Provisional application No. 61/286,571, filed on Dec.
15, 2009.**Publication Classification**(51) **Int. Cl.***F28D 1/04* (2006.01)*F28D 1/053* (2006.01)(57) **ABSTRACT**

An integrated cooling apparatus for actively cooling one or more electronic components in an electronic device such as a computer is provided. The cooling apparatus includes a radiator and a pump integrally attached to the radiator. The pump can include a pump housing having an first pump housing member attached to the radiator and a second pump housing member detachably securable to the upper pump housing member. The cooling system includes a flow inlet and a flow outlet for attaching hoses or conduits to the radiator for actively moving a liquid coolant to and from an external cooling block or cooling plate. The external cooling block or cooling plate can be attached to the electronic component to be cooled, such as a computer graphics card, microprocessor, or other circuit component.





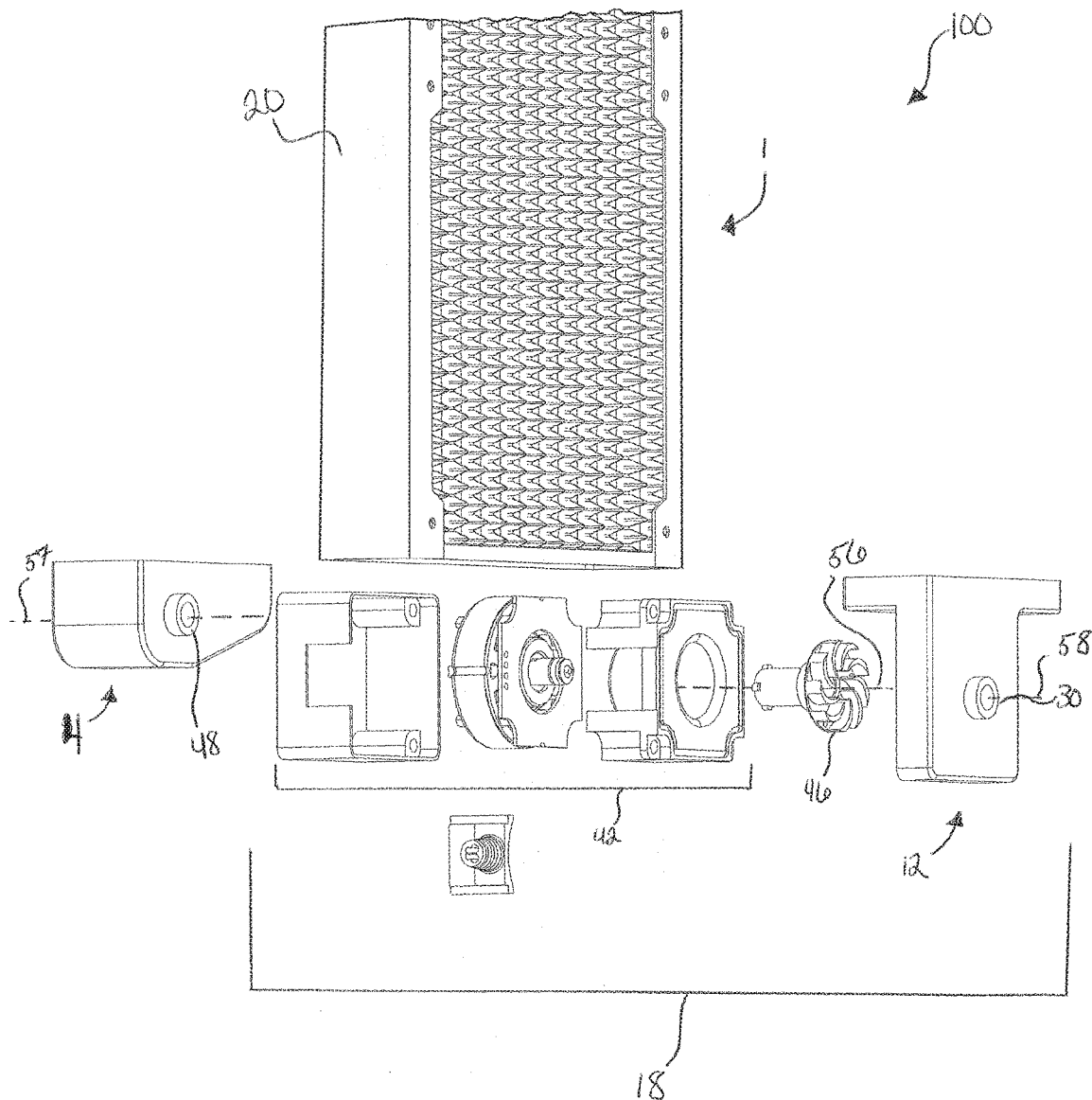


FIG. 2

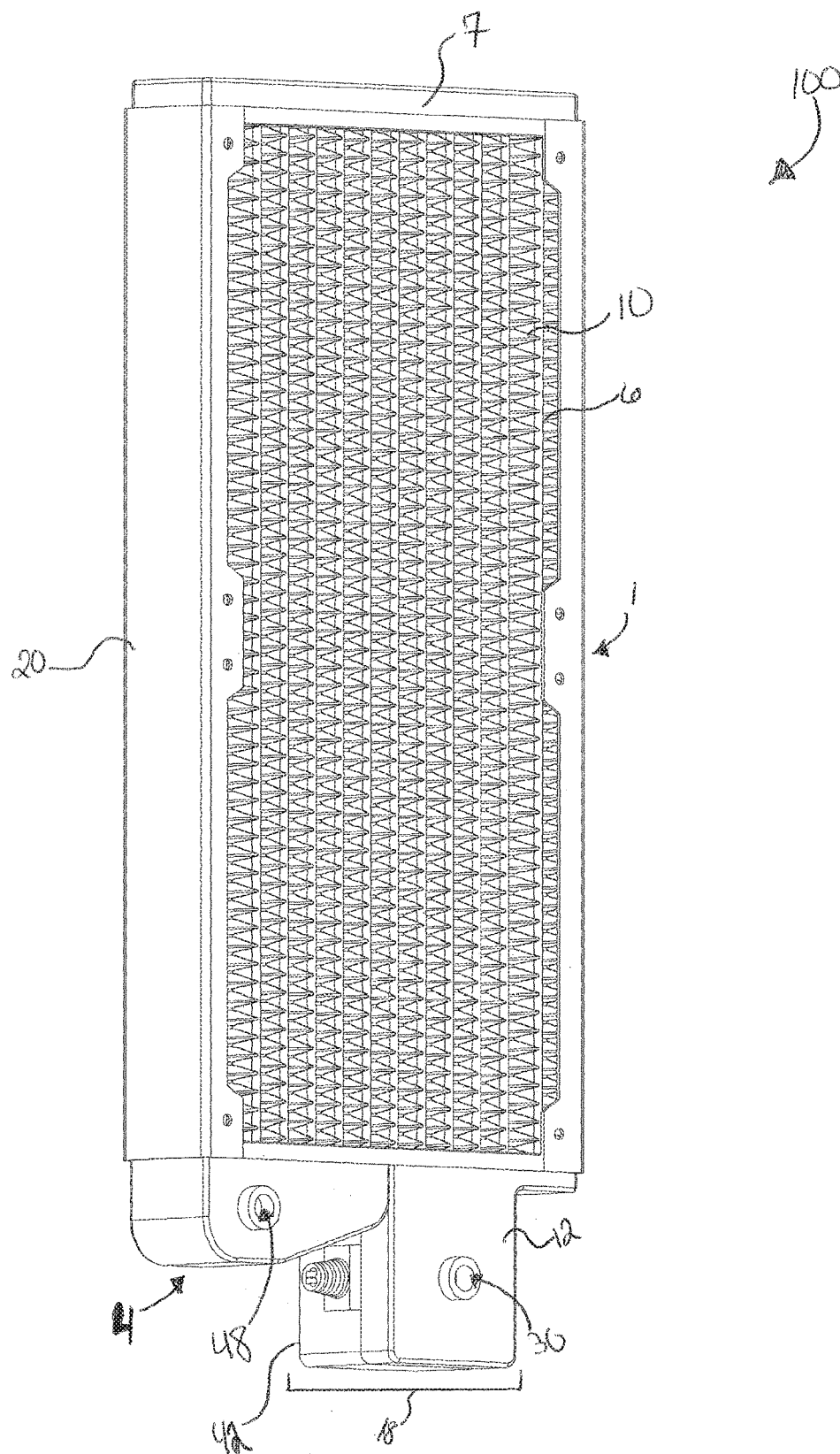


FIG. 3

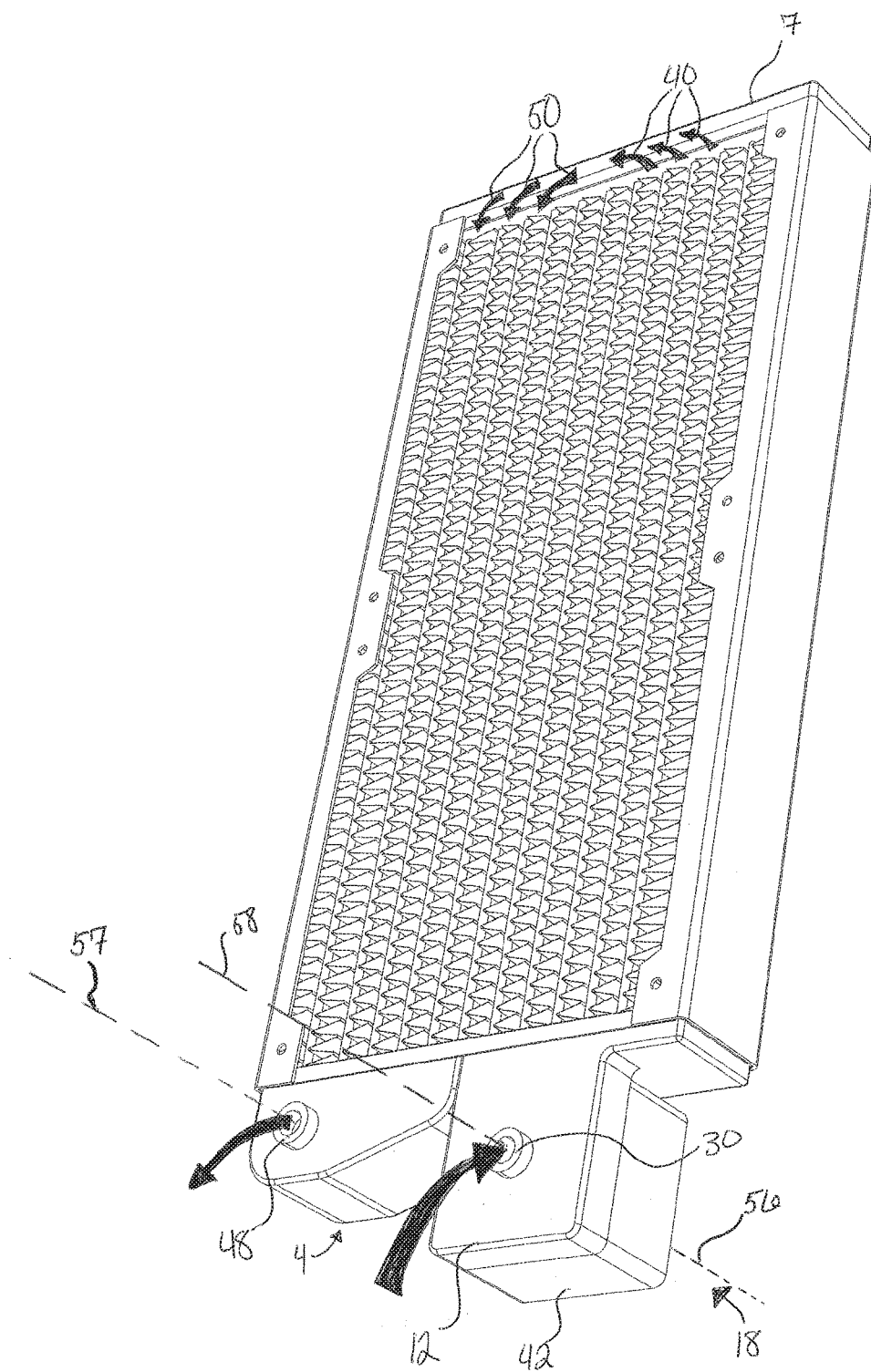


FIG. 4

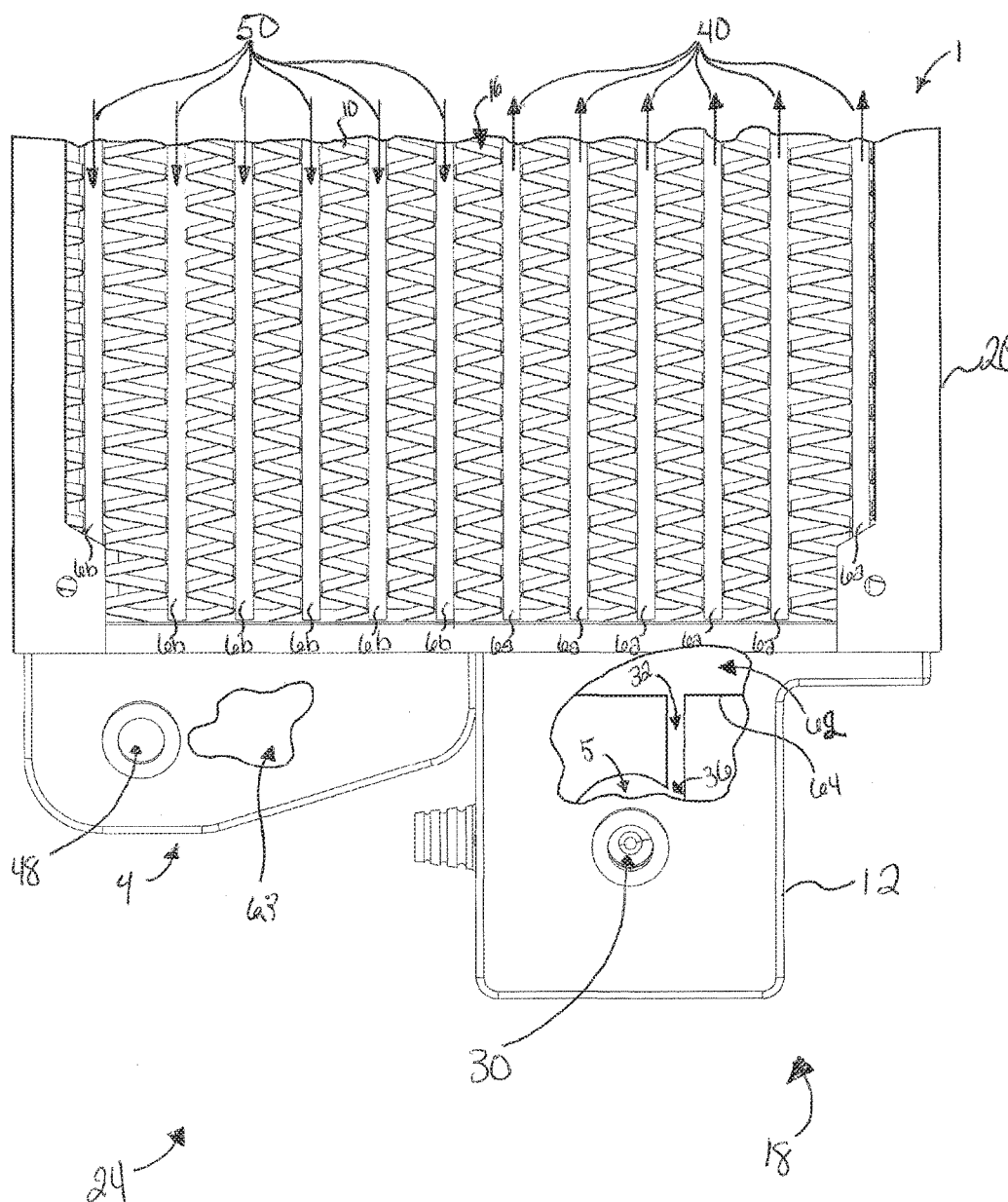


FIG. 5

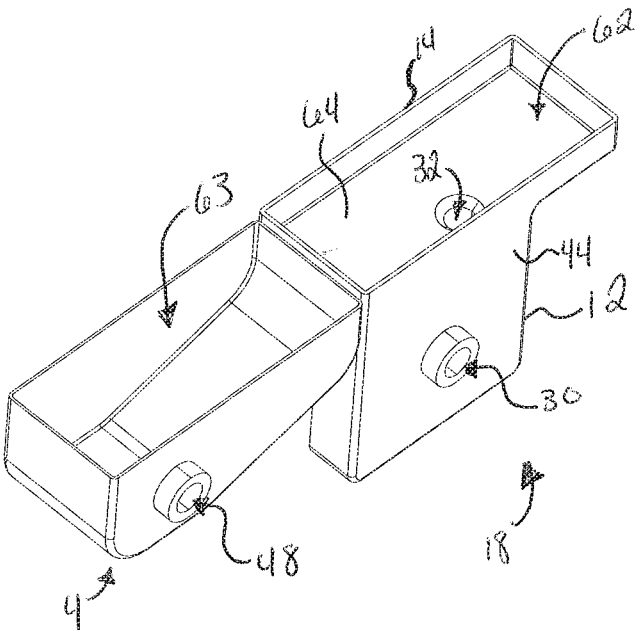


FIG. 6

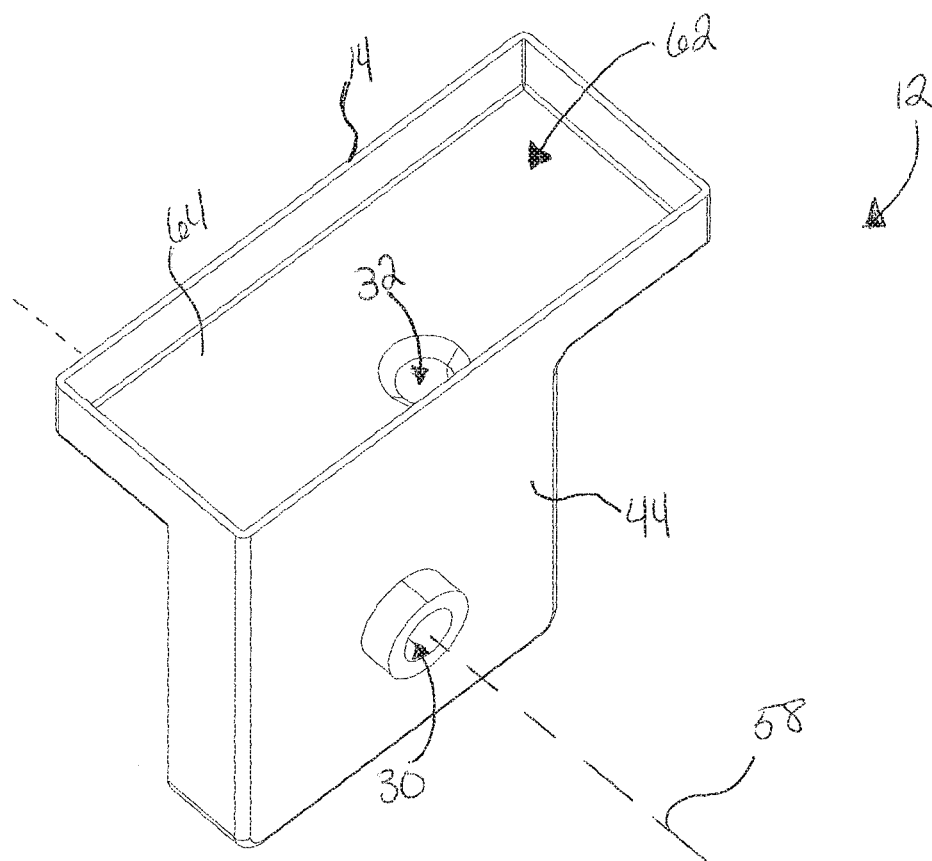


FIG. 7

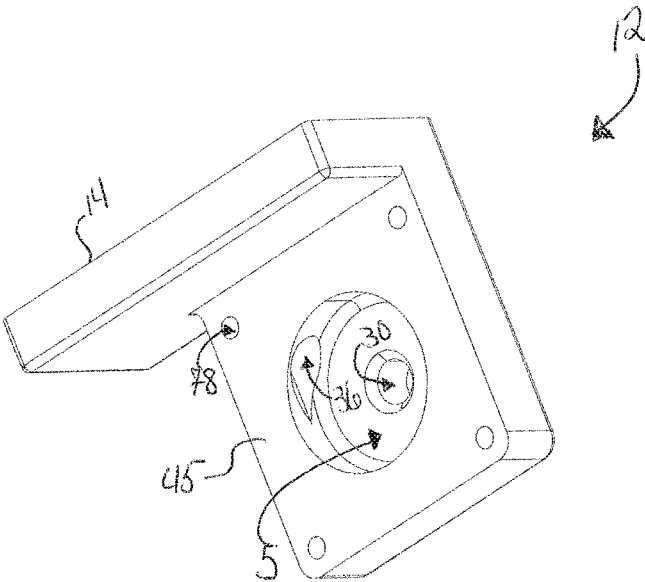


FIG. 8

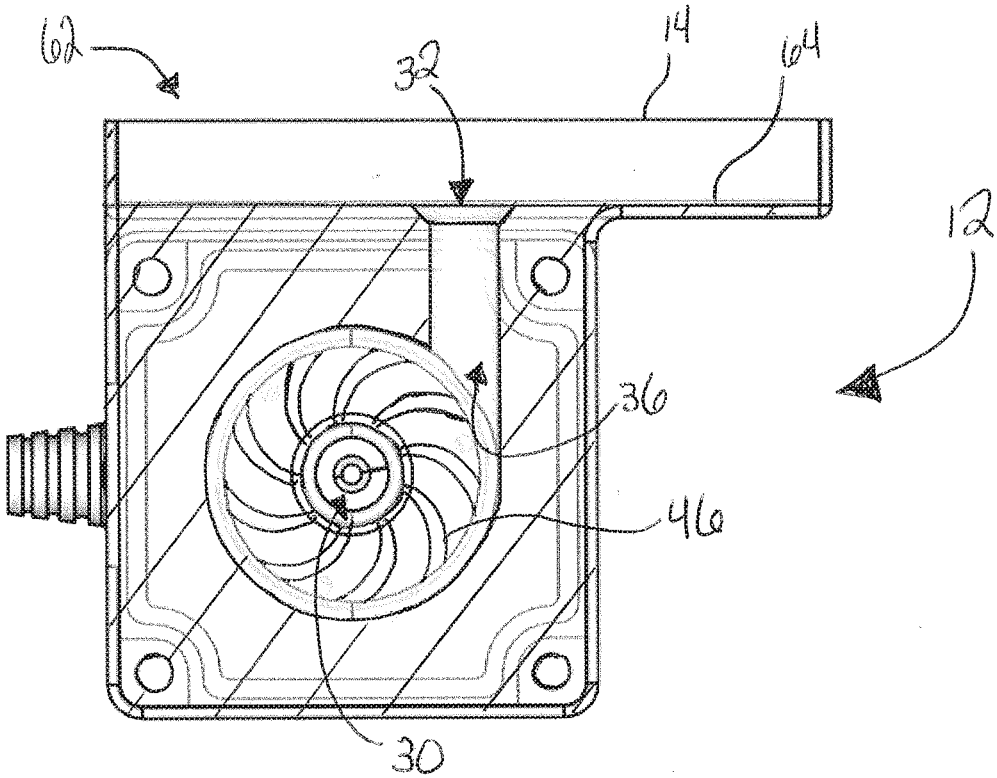


FIG. 9

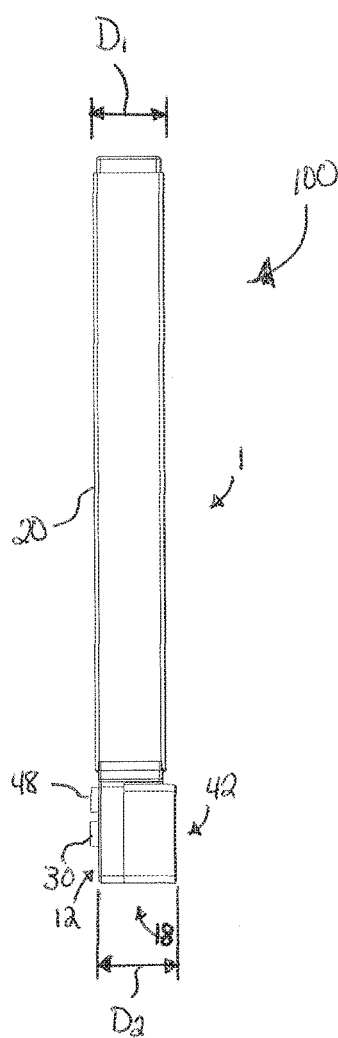


FIG. 10

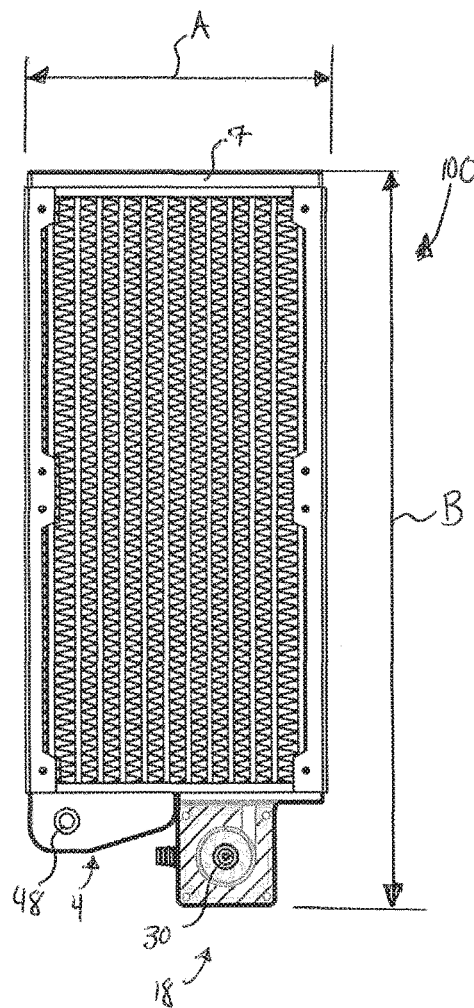


FIG. 11

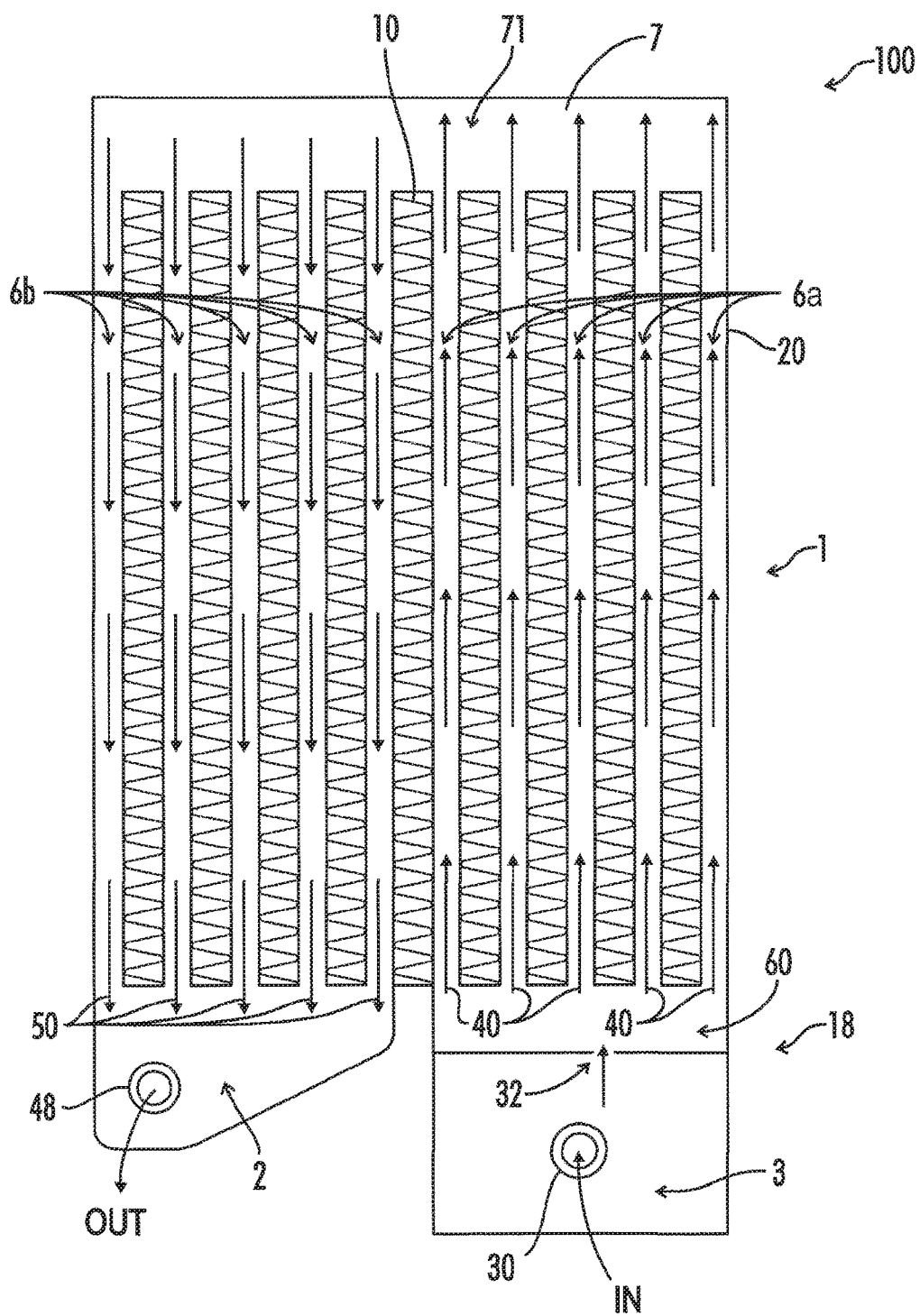


FIG. 12

RADIATOR WITH INTEGRATED PUMP FOR ACTIVELY COOLING ELECTRONIC DEVICES

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 12/969,284 filed Dec. 15, 2010 entitled "RADIATOR WITH INTEGRATED PUMP FOR ACTIVELY COOLING ELECTRONIC DEVICES," which claims priority to U.S. Provisional Patent Application No. 61/286,571 filed Dec. 15, 2009 entitled "A Radiator with Integrated Pump for Water Cooled Computer Systems," which are hereby incorporated by reference in their entireties.

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STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0003] Not Applicable

REFERENCE TO SEQUENCE LISTING OR COMPUTER PROGRAM LISTING APPENDIX

[0004] Not Applicable

BACKGROUND

[0005] The present invention relates generally to active cooling systems and more particularly to liquid heat exchanger systems for removing heat from electronic components and devices.

[0006] Consumer electronic devices such as personal computers commonly utilize microprocessors and other circuit components that generate heat. Such circuit components can include for example central processing units, video graphics processing units, chip sets, and memory modules. During use, heat generated within these circuit components must be removed to avoid both damage to the electronic device and reduction in device performance.

[0007] Conventional active cooling systems have been developed to extract heat from circuit components in electronic device applications such as personal computers. Such conventional active cooling systems can include the use of fans mounted on or near a circuit component to force air across the circuit component or across a heat exchanger mounted to the circuit component. Forced convection can transfer heat away from the circuit component in these conventional systems. Another conventional active cooling system includes the use of a closed-loop fluid circuit including a cooling fluid, a fluid reservoir, a pump, a heat exchanger or radiator and a contact block. The contact block generally includes the region where the cooling fluid engages in thermal contact with the heat generating circuit component, i.e. a central processing unit, microprocessor, graphics card, etc. Also, in such conventional systems, movement of the cooling fluid through the closed-loop system is provided by an external pump.

[0008] In many applications, the space surrounding the circuit component to be cooled inside the electronic device

does not provide adequate room for a closed-loop active liquid cooling system. Thus, it may be necessary to position one or more cooling system components outside the electronic device housing where there is sufficient space. This type of system can be referred to as remote cooling.

[0009] One problem associated with conventional active remote cooling systems of this nature involves the use of numerous individual components. For example, some conventional systems include a pump coupled to a reservoir, a heat exchanger, and a contact block engaging the circuit feature to be cooled, wherein each system component is connected by one or more conduits or hoses. This type of system requires at least three connection hoses—an outlet hose extending from the heat exchanger to the pump, a delivery hose extending from the pump to the contact block, and an inlet hose extending from the contact block back to the heat exchanger. Each hose end must be securely connected to a system component, leading to at least six hose connection locations. Such conventional designs requiring three hoses and a standalone pump undesirably add complexity and potential leakage locations to the active cooling system.

[0010] Another problem associated with some conventional active liquid cooling systems for electronic devices includes the placement of the inlet and outlet orifices in the heat exchanger. For example, U.S. Pat. No. 6,234,240 to Cheon teaches a fanless cooling system for a computer having a reservoir with an inlet opening generally positioned at a higher elevation than the exit opening. By positioning an opening in the reservoir at a relatively high elevation on the electronic device, such conventional devices create an enhanced possibility of damage to circuit components if a leak should develop at the elevated opening position during use.

[0011] Another problem associated with conventional active liquid cooling systems for electronic devices is placement of all cooling system components inside the electronic device. Such internal system component placement can require disassembly of the electronic device if replacement, repair, or alteration of any individual component is necessary. Disassembly of the electronic device in such instances can be time consuming and costly and can increase the likelihood of damage to other system components or the electronic device itself during disassembly.

[0012] Another problem associated with some conventional active liquid cooling devices includes the space requirements inside the electronic device. The electronic device may have limited room allocated to the placement of a liquid cooling device and the various components of the liquid cooling device and how they are assembled for liquid coolant flow. The liquid cooling device may require additional space, which is not available in the electronic device.

[0013] Another problem associated with some conventional active liquid cooling devices includes the orientation of the devices and specifically the flow orientation. Some conventional liquid cooling devices may be less efficient and effective at circulating coolant through the device because of inefficiencies in the fluid dynamics.

[0014] What is needed then are additional improvements in the devices and associated methods of actively cooling circuit components in electronic devices using closed loop liquid circulation systems.

BRIEF SUMMARY

[0015] One embodiment of the present disclosure provides a cooling apparatus. The cooling apparatus includes a radiator defining a radiator plane and having a first longitudinal tube with a first flow direction and a second longitudinal tube with a second flow direction opposite the first flow direction. The apparatus also includes a flow inlet port in fluid communication with the first longitudinal tube and a pump having a first pump housing member detachably coupled to a second pump housing member. The apparatus further includes a pump rotor defining a rotor axis of rotation and disposed in the pump between the first pump housing member and the second pump housing member. The rotor axis of rotation is perpendicular to the radiator plane.

[0016] Another embodiment of the present disclosure provides a cooling apparatus a radiator having a first longitudinal tube with a first flow direction and a second longitudinal tube with a second flow direction opposite the first flow direction. The apparatus further includes a pump having a first pump housing member detachably coupled to a second pump housing member, a flow inlet port positioned on the pump and in fluid communication with the first longitudinal tube, and a pump rotor disposed in the pump between a first pump housing member and a second pump housing member. When the pump is activated, the liquid coolant enters through the flow inlet port into the pump and the pump pushes the liquid coolant into the first longitudinal tube in the first flow direction.

[0017] Yet another embodiment includes a cooling apparatus having a radiator defining a radiator depth and having a first longitudinal tube with a first flow direction and a second longitudinal tube with a second flow direction opposite the first flow direction. The apparatus further includes a flow inlet port in fluid communication with the first longitudinal tube, a pump defining a pump depth and having a first pump housing member detachably coupled to a second pump housing member, and a pump rotor disposed in the pump between the upper and lower pump housing members and defining a rotor axis of rotation, wherein the pump depth is at most 30 percent greater than the radiator depth.

[0018] Numerous other objects, features, and advantages of the present disclosure will be readily apparent to those skilled in the art upon a reading of the following description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 is a front view of an exemplary embodiment of an integrated cooling apparatus with a radiator and an integrated pump.

[0020] FIG. 2 is a partially exploded perspective view of an exemplary embodiment of an integrated cooling apparatus with a radiator and an integrated pump.

[0021] FIG. 3 is a perspective view of an exemplary embodiment of an integrated cooling apparatus.

[0022] FIG. 4 is a perspective view of an exemplary embodiment of the integrated cooling apparatus demonstrating the flow direction of liquid coolant.

[0023] FIG. 5 is a partially broken away front elevation view of an exemplary embodiment of an integrated cooling apparatus including a radiator and integrated pump housing.

[0024] FIG. 6 is a top perspective view of an exemplary embodiment of a first pump housing member of an integrated cooling apparatus and an outlet chamber.

[0025] FIG. 7 is a top perspective view of an exemplary embodiment of a first pump housing member.

[0026] FIG. 8 is a bottom perspective view of an exemplary embodiment of a first pump housing member.

[0027] FIG. 9 is a sectional view of an exemplary embodiment of a first pump housing member.

[0028] FIG. 10 is a side view of an exemplary embodiment of an integrated cooling apparatus.

[0029] FIG. 11 is a front elevation view of an exemplary embodiment of an integrated cooling apparatus with a sectional view of the pump housing member.

[0030] FIG. 12 is a schematic cross-sectional view of an exemplary embodiment of an integrated cooling system.

DETAILED DESCRIPTION

[0031] While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts that are embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use the invention and do not delimit the scope of the invention. Those of ordinary skill in the art will recognize numerous equivalents to the specific apparatus and methods described herein. Such equivalents are considered to be within the scope of this invention and are covered by the claims.

[0032] In the drawings, not all reference numbers are included in each drawing, for the sake of clarity. In addition, positional terms such as “upper,” “lower,” “side,” “top,” “bottom,” etc. refer to the apparatus when in the orientation shown in the drawing, or as otherwise described. A person of skill in the art will recognize that the apparatus can assume different orientations when in use.

[0033] Referring now to the drawings and particularly to FIG. 1, an integrated cooling apparatus for actively cooling one or more circuit components on an electronic device using a liquid coolant is generally illustrated and is designated by the numeral 100.

[0034] Referring further to FIGS. 1-4, cooling system 100 includes a radiator 1 and an integrated pump 18. Pump 18 is said to be integrated because radiator 1 and pump 18 together form a one-piece unit that can be attached to or removed from an electronic device, such as a computer, using one or more mechanical fasteners. Radiator 1, along with integrated pump 18, thus forms an integrated cooling system that includes a plug-and-play functionality with a variety of models of external cooling blocks for electronic device cooling applications. For example, various conventional external liquid cooling blocks, cooling plates, or liquid heat exchangers can be mounted on the electronic component or components to be cooled. Such conventional cooling blocks or cooling plates can be interchangeably connected to the integrated cooling apparatus 100 of the present invention because radiator 1 and integrated pump 18 are provided as a single unit. Thus, when the external cooling blocks are connected to the cooling system, a closed system is formed, meaning the cooling liquid remains within the system or circuit.

[0035] As seen in FIG. 5, radiator 1 includes a radiator housing 20 having one or more first longitudinal tubes 6a and one or more second longitudinal tubes 6b. The radiator 1 may form or define a radiator plane. The radiator plane may generally be the plane, which is defined by the length

and width of the radiator 1. In some embodiments, the first longitudinal tubes 6a and the second longitudinal tubes 6b are positioned in or along the radiator plane. Longitudinal tubes 6a and 6b are said to be longitudinal because each tube generally defines a tube aspect ratio wherein the tube length is greater than the tube diameter. The number of first longitudinal tubes 6a and the number of second longitudinal tubes 6b can be varied depending on several factors, including for example but not limited to the required level of heat extraction, the performance characteristics of pump 18 and the available space on the electronic device for mounting radiator 1. In some embodiments, radiator 1 includes a first plurality of longitudinal tubes 6a and a second plurality of longitudinal tubes 6b, as seen in FIG. 5. In other embodiments, radiator 1 includes only one first longitudinal tube 6a and only one second longitudinal tube 6b to minimize radiator profile (not shown). Referring further to FIG. 5, in some embodiments, radiator 1 includes six or more first longitudinal tubes 6a and six or more second longitudinal tubes 6b.

[0036] A tube gap 16 is defined between at least one first longitudinal tube 6a and at least one second longitudinal tube 6b. One or more heat exchanger fins 10 are transversely disposed across tube gap 16 between the adjacent longitudinal tubes. Each heat exchanger fin 10, as seen in FIG. 5, can be positioned at an angle relative to adjacent tubes. Each heat exchanger fin 10 generally spans the tube gap 16 between adjacent tubes so that air or another gas can be passed through radiator 1 across the surfaces of heat exchanger fins 10 and tubes 6a, 6b for convecting heat away from radiator 1.

[0037] As seen in FIG. 5 and FIG. 12, in some embodiments, each first longitudinal tube 6a includes a first flow direction 40, and each second longitudinal tube 6b includes a second flow direction 50. The flow directions 40 and 50 generally indicate the direction that a liquid coolant will travel through each respective longitudinal tube 6. For example, in some embodiments, liquid coolant travelling through one or more first longitudinal tubes 6a will travel away from the inlet port 30 positioned on the bottom end 24 of radiator 1. Also, liquid coolant travelling through one or more second longitudinal tubes 6b will travel generally toward flow outlet 48, also positioned on the bottom end 24 of radiator 1. Thus, in some embodiments, the first and second flow directions 40, 50 are substantially opposite.

[0038] Referring again to FIGS. 1-4, radiator 1 includes a flow inlet 30 and a flow outlet 48. Flow inlet 30 is generally defined as an orifice through which a gas or a fluid can pass to enter apparatus 100. Similarly, flow outlet 48 is generally defined as an orifice through which a gas or a fluid can pass to exit apparatus 100. Generally, an inlet fitting can be coupled to flow inlet 30, and an outlet fitting can be coupled to flow outlet 48. In some embodiments, inlet fitting and outlet fitting each may include a barbed hose connector with a threaded stem, and each fitting can threadedly engages its corresponding orifice 30, 48, respectively. During use, an inlet hose or conduit can be secured to the inlet fitting for delivering fluid into the cooling system 100, and an outlet hose or conduit can be secured to the outlet fitting for delivering fluid from the heat exchanger to the cooling block or heat exchanger engaging the component to be cooled in thermal contact.

[0039] In some embodiments, radiator housing 20 includes a first, or upper end 22, and a second, or lower end

24. In some embodiments, the flow inlet 30 and the flow outlet 48 are both positioned on the same end of heat exchanger body 20. As seen in FIG. 1, in one embodiment, flow inlet 30 and flow outlet 48 are both positioned on the lower end 24 of heat exchanger body 20. As such, liquid coolant entering flow inlet 30 passes generally up through heat exchanger body 20 toward upper end 22 and subsequently changes directions in plenum 7 before passing back down toward lower end 24 to exit through flow outlet 48. In embodiments where flow inlet 30 and flow outlet 48 are positioned on the same end of cooling apparatus 100, management of fluid hoses is improved over conventional designs as inlet and exit hoses are positioned spatially near each other.

[0040] Liquid coolant is forced through integrated cooling system 100 by a mechanical pump 18 attached to radiator 1. Pump 18 includes a pump housing. The pump housing in some embodiments includes a first pump housing member 12 and a second pump housing member 42. The second pump housing member 42 can be detachably securable to first pump housing member 12.

[0041] Referring now to FIG. 6, an exemplary embodiment of a first pump housing member 12 and an outlet reservoir housing 4 are generally depicted. The outlet reservoir housing 4 may be formed to provide an outlet reservoir 63. Fluids circulating through the radiator 1 may collect in the outlet reservoir 63 until the fluid exits the cooling system 100 through the flow outlet 48. The first pump housing member can be formed to provide a pump reservoir 62.

[0042] Referring to FIG. 7-9, an exemplary embodiment of a first pump housing member 12 is generally illustrated. First pump housing member 12 can be integrally formed on radiator 1 including radiator housing 20. First pump housing member 12 in other embodiments can be formed separately using a forging, casting, machining, molding, or another suitable manufacturing technique and can be subsequently attached to radiator 1. First pump housing member 12 can include a metal, plastic, ceramic, or other suitable rigid material. Preferably, first pump housing member 12 includes a nonreactive and noncorrosive material that will not chemically react or corrode when exposed to a liquid coolant such as water or ethylene glycol. First pump housing member 12 includes a housing wall 14 that extends generally upward from first pump housing member 12. Housing wall 14 defines an outlet reservoir cavity 60 that is positioned on radiator 1 to feed liquid coolant entering one or more of the plurality of first longitudinal tubes 6a. Housing wall 14 can be integrally formed on radiator 1 or can be attached to radiator 1 using a weld or using another suitable mechanical fastening means. First pump housing member 12 also includes a lateral plate 44 extending substantially downward from first pump housing member 12. Specifically, the lateral plate 44 may extend from the reservoir wall 64. Plate 44 generally includes a bottom plate surface 45 shaped for engaging second pump housing member 42. Bottom plate surface 45 can include a plurality of stud passages 78 defined in second pump housing member 42. Each stud passage 78 can be shaped to receive a pump housing fastener. In some embodiments, each stud passage 78 includes a threaded region for threadedly engaging a corresponding threaded region on a pump housing fastener.

[0043] Also seen in FIG. 7, first pump housing member 12 in some embodiments includes inlet port 30. Inlet port 30 is

generally not open to pump reservoir 62 on first pump housing member 12. Instead, in some embodiments, inlet port 30 is open to an inlet chamber 5 positioned below pump reservoir 62, seen in FIG. 6, via centrifugal exit port 36, seen in FIG. 8. In some embodiments, inlet chamber 5 includes a circular shape for allowing a pump impeller, or pump rotor 46, to rotate inside inlet chamber 5. The pump rotor 46 may be received by the inlet chamber 5, as the inlet chamber 5 may be shaped to receive, at least partially, the pump rotor 46. The pump rotor 46 may also be partially received by the second pump housing member 42. Centrifugal exit port 36 is aligned substantially tangential to the circular profile of inlet chamber 5 in some embodiments to provide flow of liquid coolant from inlet chamber 5 as pump rotor 46 rotates. When the pump rotor 46 is rotating, liquid coolant is forced from the inlet chamber 5, through the centrifugal exit port 36 and into the pump reservoir 62. Because of the higher pressure in the pump reservoir 62, liquid coolant is driven into the first longitudinal tubes 6a to the plenum 7 and into the second longitudinal tubes 6b.

[0044] Referring still to FIG. 7, a reservoir wall 64 spans the bottom of pump reservoir 62 and separates pump reservoir 62 from inlet chamber 5, as seen in FIGS. 5-7. Reservoir wall 64 includes an internal exit port 32 that defines a passage for liquid coolant to travel between pump reservoir 62 and inlet chamber 5, allowing liquid coolant to be engaged by pump rotor 46 and moved out of the pump housing 19 through the centrifugal exit port 36 and the pump reservoir 62 into the longitudinal tubes 6. As pump rotor 46 spins and forces liquid coolant through longitudinal tubes 6, a negative pressure is created in the hoses feeding the inlet chamber 5 that pulls additional liquid coolant through inlet port 30 from the hoses. Pump reservoir 62 feeds liquid coolant from one or more first longitudinal tubes 6a and generally maintains a fluid volume of liquid coolant housed in pump reservoir 62 during use.

[0045] Referring again to FIGS. 1-4, in some embodiments, pump rotor 46 is generally included in the pump housing 19 between first pump housing member 12 and second pump housing member 42. Pump rotor 46 generally defines a rotor axis of rotation 56 about which pump rotor 46 rotates during use. In some embodiments, rotor axis of rotation 56 is substantially perpendicular to the second flow direction 50 of liquid coolant passing through one or more second longitudinal tubes 6b, seen in FIG. 4 and FIG. 9. In such embodiments, liquid coolant can be received into cooling apparatus 100 along rotor axis of rotation 56 as the flow inlet axis 58 and the axis of rotation 56 are in the same position. Thus, liquid coolant is received into the cooling apparatus along the flow inlet axis 58 and the rotor axis of rotation 56 because the flow inlet axis and the rotor axis of rotation 46 are aligned or substantially aligned. Additionally, liquid coolant can be ejected from cooling apparatus 100 along flow outlet axis 57. In some embodiments, flow outlet axis 57 is substantially parallel to the rotor axis of rotation 56 and the flow inlet axis 58. Additionally, in some embodiments, flow outlet axis 57 is substantially perpendicular to second flow direction 50, and flow inlet axis 58 is substantially perpendicular to first flow direction 40.

[0046] Referring to FIGS. 4, 5, and 12, in some embodiments, the liquid coolant generally flows from the flow inlet 30 along the flow inlet axis 58, into the inlet chamber 5, where the rotor 46 forces the liquid coolant through the centrifugal exit port 36 and the internal exit port 32, which

feeds into the inlet pump 62. The centrifugal exit port 36 and internal exit port 32 are generally aligned in such that they are parallel to the longitudinal tubes 6 and perpendicular to the rotor axis of rotation 56 and inlet flow axis 58. As the rotor 46 continues to force liquid coolant into the pump reservoir 62, pressure rises in the pump reservoir 62. The liquid coolant is forced into the first longitudinal tubes 6a and travels through the first longitudinal tubes 6a. In some embodiments, liquid coolant being pushed by the pump 18 into the first longitudinal tubes 6a immediately or substantially immediately with few intermediary parts may provide a more efficient system because more work is required to elevate the liquid coolant when the radiator 1 is oriented upright. When the rotor 46 is pushing liquid coolant via high pressure in the pump reservoir 62 directly into the first longitudinal tubes 6a, the fluid dynamics and internal friction are minimized. After the liquid coolant has passed from the first longitudinal tubes 6a into the plenum 7, the liquid coolant then travels back down through the second longitudinal tubes 6b and into the outlet reservoir 63. The liquid coolant then passes from the outlet reservoir 63 through the flow outlet 48 and out of the cooling apparatus 100.

[0047] Also seen in FIGS. 1-5 and FIGS. 10-12, in some embodiments, a plenum 7 is disposed on radiator 1. More particularly, plenum 7 can be positioned on radiator housing 20 and can form a plenum cavity, or a reservoir 71, seen for example in FIG. 12, for storing liquid coolant contained in radiator 1. As seen in FIG. 12, in some embodiments, the first plurality of longitudinal tubes 6a is positioned to deliver liquid coolant into the reservoir defined by plenum 7. In addition, the second plurality of longitudinal tubes 6b is positioned to receive liquid coolant from the reservoir defined by plenum 7. Thus, liquid coolant enters plenum 7 from one or more first longitudinal tubes 6a, as indicated by arrows 40, and exits plenum 7 through one or more second longitudinal tubes 6b, as indicated by arrows 50.

[0048] As seen in FIGS. 4 and 10, in some embodiments when the integrated pump 18 is oriented such that the rotor axis of rotation 56 is perpendicular to the flow directions 40, 50, the integrated pump 18 may also allow the cooling apparatus 100 to maintain a smaller footprint, which may be advantageous in computers and other systems where space is limited. A smaller form factor of the cooling apparatus 100 may allow assembly or removal of the cooling apparatus 100 from the computer without having to disassemble the computer, as the depth of the cooling device 100 may be either equivalent or substantially similar throughout the device, meaning the depth of the integrated pump 18 may be similar to the depth of the radiator 1. In some embodiments, the pump depth D_2 is at most 30 percent greater than the radiator depth D_1 . In some embodiments, the integrated pump 18 may be 60 mm by 60 mm. In other embodiments, the integrated pump 18 may be 40 mm by 40 mm. Various integrated pumps 18 may be implemented in various embodiments, including integrated pumps 18 using a variety of bearings and shaft retention systems. The implementation of various bearings and shaft retention systems may provide for the form factor as described previously.

[0049] Referring again to FIG. 1, in some embodiments, an outlet reservoir 63 is defined in cooling apparatus 100 between flow outlet 48 and one or more of second longitudinal tubes 6b. Outlet reservoir housing 4 can include a cavity or outlet reservoir 63 defined on the interior of radiator 1 positioned for receiving a volume of liquid

coolant after the liquid coolant exits one or more of second longitudinal tubes 66. During use, the liquid coolant enters outlet reservoir 63 and passes through outlet reservoir 63 before exiting the cooling apparatus 100 through the flow outlet 48.

[0050] Referring now to FIG. 11, in some embodiments, a cooling apparatus 100 includes a radiator 1 with integrated pump 18 having a width A and a height B. In some embodiments, B is greater than A so that the heat transfer performance characteristics of radiator 1 are achieved while simultaneously allowing cooling apparatus 100 to be mounted on a computer chassis or electronic device. In other embodiments, the ratio of A divided by B is between about 0.1 and about 0.9. In further embodiments, desired heat transfer and form factor characteristics are achieved by providing a ratio of A divided by B between about 0.2 and about 0.4.

[0051] A further embodiment of the present invention provides a method of cooling an electronic device, including the steps of: (a) providing an active cooling system having a radiator and an integrated pump attached to the radiator; (b) passing heated liquid into the radiator through a flow inlet; (c) forcing the liquid through a first longitudinal tube in a first flow direction away from the flow inlet using a mechanical pump; (d) passing the liquid through a plenum disposed on the end of the radiator opposite the flow inlet; (e) forcing the liquid through a second longitudinal tube in a second flow direction opposite the first flow direction; (f) collecting the liquid in an outlet reservoir interior to the radiator; (g) passing the liquid from the outlet reservoir through the flow outlet.

[0052] Thus, although there have been described particular embodiments of the present invention of a new and useful RADIATOR WITH INTEGRATED PUMP FOR ACTIVELY COOLING ELECTRONIC DEVICES, it is not intended that such references be construed as limitations upon the scope of the invention except as set forth in the following claims.

What is claimed is:

1. A cooling apparatus, comprising:

- a radiator defining a radiator plane and having a first longitudinal tube with a first flow direction and a second longitudinal tube with a second flow direction opposite the first flow direction;
- a flow inlet port in fluid communication with the first longitudinal tube;
- a pump having a first pump housing member detachably coupled to a second pump housing member; and
- a pump rotor defining a rotor axis of rotation and disposed in the pump between the first pump housing member and the second pump housing member,

wherein the rotor axis of rotation is perpendicular to the radiator plane.

2. The cooling apparatus of claim 1, wherein the flow inlet port is disposed about a flow inlet axis and the flow inlet axis is substantially parallel to the rotor axis of rotation.

3. The cooling apparatus of claim 1, further comprising a flow outlet port, wherein the flow outlet port and the flow inlet port are both positioned proximate a first end of the radiator.

4. The cooling apparatus of claim 1, wherein the first pump housing member further comprises:

- a reservoir wall defining an internal exit port; and
- a second exit port defined in the first pump housing member, wherein the second exit port and the internal exit port are in fluid communication across the reservoir wall.

5. The cooling apparatus of claim 4, further comprising:

- a pump reservoir in fluid communication with the first longitudinal tube; and

- an inlet chamber positioned proximate the reservoir wall, wherein the inlet chamber and the pump reservoir are in fluid communication via the internal exit port and the second exit port.

6. The cooling apparatus of claim 5, wherein the inlet chamber is substantially circular and shaped to receive at least a portion of the pump rotor.

7. The cooling apparatus of claim 6, wherein the second exit port is aligned substantially tangential to the inlet chamber.

8. The cooling apparatus of claim 7, wherein the first pump housing member further comprises a lateral plate extending from the reservoir wall and operable to receive the second pump housing member.

9. The cooling apparatus of claim 8, wherein the second pump housing member defines a recess configured to receive at least a second portion of the pump rotor such that the pump rotor is disposed between the second pump housing member and the first pump housing member when the second pump housing member is coupled to the first pump housing member.

10. A cooling apparatus using liquid coolant, comprising:

- a radiator having a first longitudinal tube with a first flow direction and a second longitudinal tube with a second flow direction opposite the first flow direction;
- a pump having a first pump housing member detachably coupled to a second pump housing member;
- a flow inlet port positioned on the pump and in fluid communication with the first longitudinal tube; and
- a pump rotor disposed in the pump between the first pump housing member and the second pump housing member,

wherein, when the pump is activated, the liquid coolant enters through the flow inlet port into the pump and the pump pushes the liquid coolant into the first longitudinal tube in the first flow direction.

11. The cooling apparatus of claim 10, wherein the radiator defines a radiator plane and the pump rotor defines a rotor axis of rotation perpendicular to the radiator plane.

12. The cooling apparatus of claim 10, wherein the flow inlet port is disposed about a flow inlet axis and the flow inlet axis is substantially along to the rotor axis of rotation such that, when the pump is activated, the liquid coolant enters the flow inlet port along the flow inlet axis and substantially parallel to the rotor axis of rotation.

13. The cooling apparatus of claim 10, further comprising a flow outlet port, wherein the flow outlet port and the flow inlet port are both positioned proximate a first end of the radiator.

14. The cooling apparatus of claim 10, wherein the first pump housing member further comprises:

- a reservoir wall defining an internal exit port; and
- a second exit port defined in the first pump housing member, wherein the second exit port and the internal

exit port are in fluid communication across the reservoir wall, wherein the liquid coolant, when the pump is activated, is pushed through the second exit port and out the internal exit port.

15. The cooling apparatus of claim **14**, further comprising:

a pump reservoir in fluid communication with the first longitudinal tube; and

an inlet chamber positioned proximate the reservoir wall, wherein the inlet chamber and the pump reservoir are in fluid communication via the internal exit port and the second exit port such that, when the pump is activated, the liquid coolant exits the internal exit port into the pump reservoir and through the first longitudinal tube.

16. The cooling apparatus of claim **15**, wherein the inlet chamber is substantially circular.

17. A cooling apparatus comprising:

a radiator defining a radiator depth and having a first longitudinal tube with a first flow direction and a second longitudinal tube with a second flow direction opposite the first flow direction;

a flow inlet port in fluid communication with the first longitudinal tube;

a pump defining a pump depth and having a first pump housing member detachably coupled to a second pump housing member; and

a pump rotor defining a rotor axis of rotation and disposed in the pump between the first pump housing member and the second pump housing member,

wherein the pump depth is at most **30** percent greater than the radiator depth.

18. The cooling apparatus of claim **17**, wherein the radiator defines a radiator plane and the rotor axis of rotation is perpendicular to the radiator plane.

19. The cooling apparatus of claim **18**, wherein, when the pump is activated, liquid coolant enters through the flow inlet port into the pump and the pump pushes the liquid coolant into the first longitudinal tube in the first flow direction.

20. The cooling apparatus of claim **19**, wherein the flow inlet port is disposed about a flow inlet axis and the flow inlet axis is substantially along the rotor axis of rotation such that, when the pump is activated, the liquid coolant enters the flow inlet port along the flow inlet axis and substantially parallel to the rotor axis of rotation.

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