

(43) **Pub. Date:** **Aug. 3, 2006**

(52) **U.S. Cl.** **415/176**

(57) **ABSTRACT**

A heatsink apparatus has a radiator and a centrifugal pump in a closed circulation channel for circulating a coolant, wherein the centrifugal pump contacting a heat-generating component dissipates heat from the heat-generating component through heat exchange with the coolant. The centrifugal pump includes: a lower casing provided with a contact surface that contacts the heat-generating component; an upper casing; a ring-shaped sealing member provided between the lower and upper casings so as to form a round heat transfer chamber between the ring-shaped sealing member and the lower casing and to form a pump chamber that houses an impeller between the ring-shaped sealing member and the upper casing; a guiding member provided protruding on the lower casing to make the round heat transfer chamber a circulation channel; and the round heat transfer chamber connecting to a through-hole formed in a central portion of the ring-shaped sealing member.

(30) **Foreign Application Priority Data**

Publication Classification

(51) **Int. Cl.**
F04D 29/58 (2006.01)

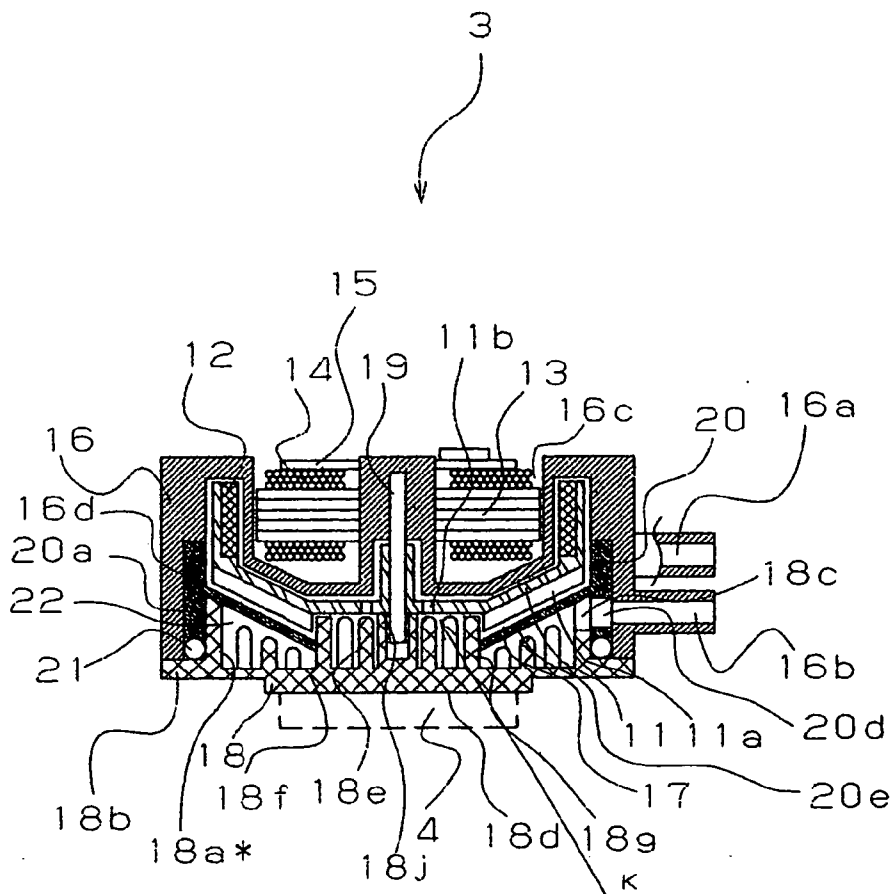


FIG. 2

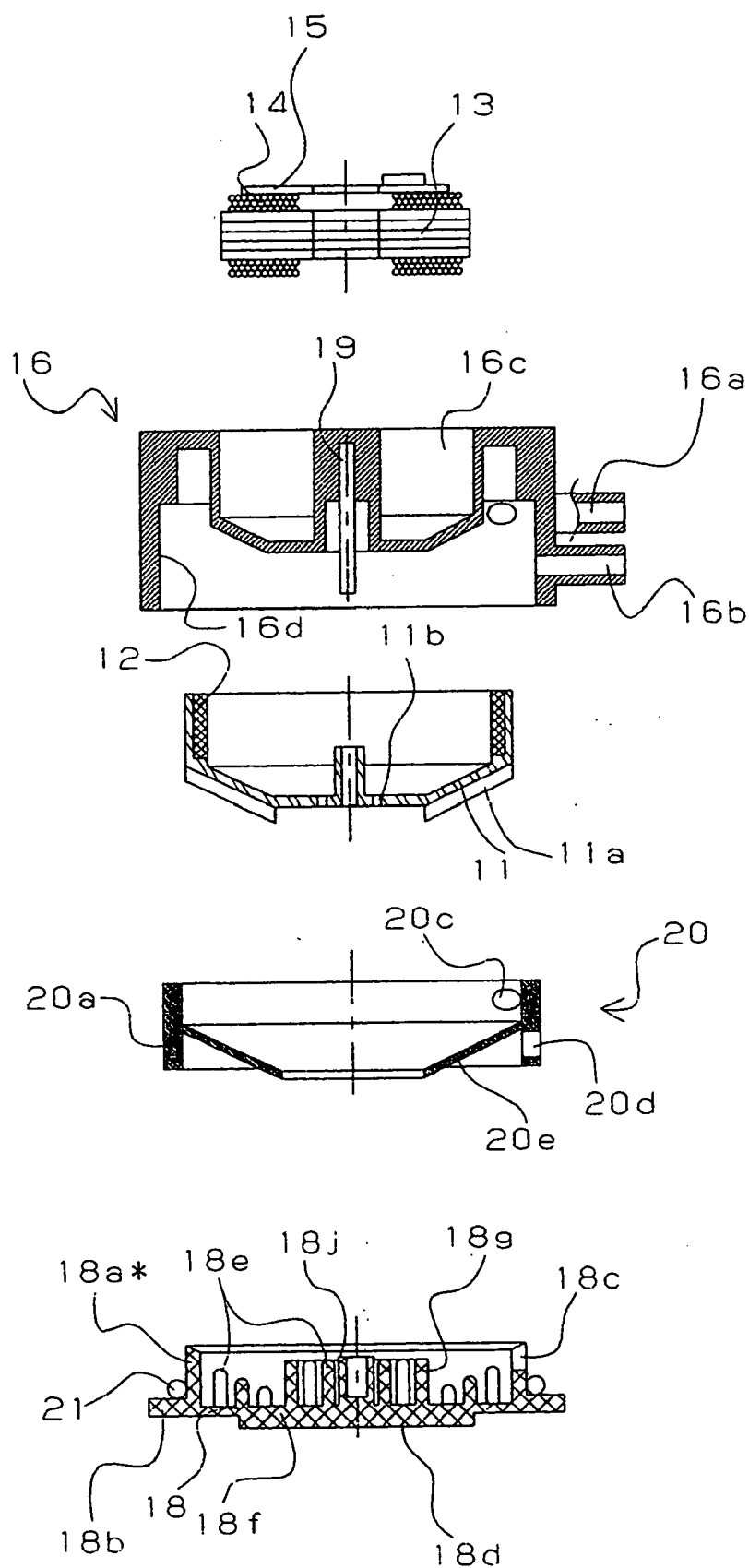


FIG. 3

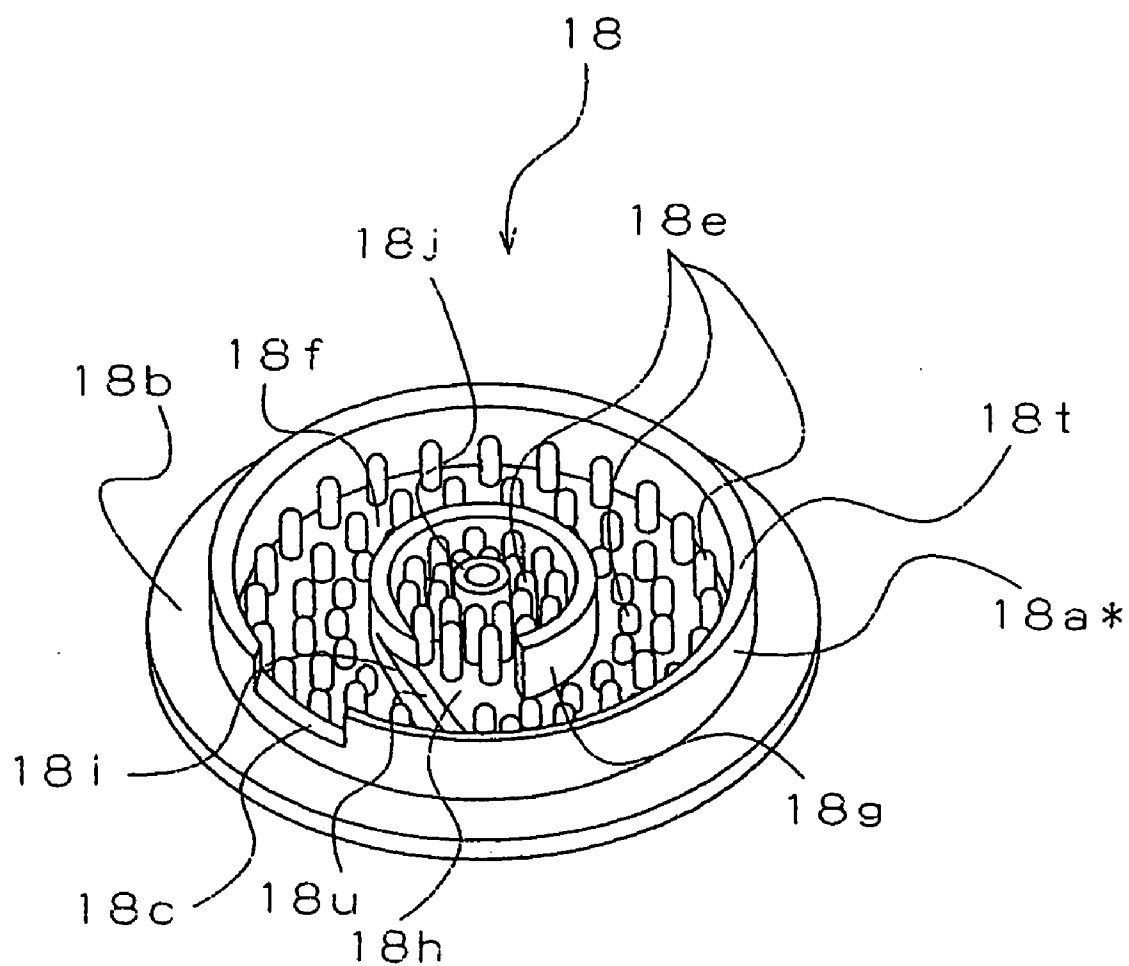


FIG. 4

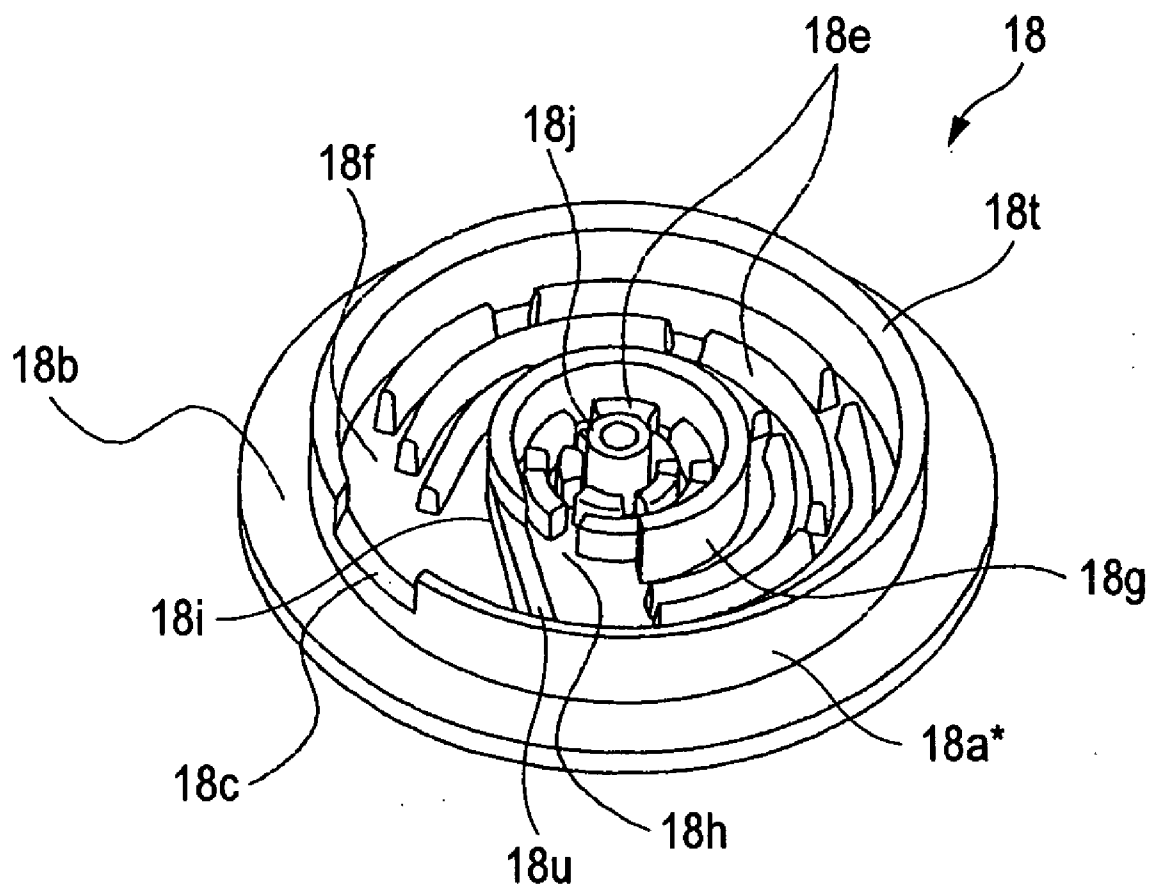


FIG. 5

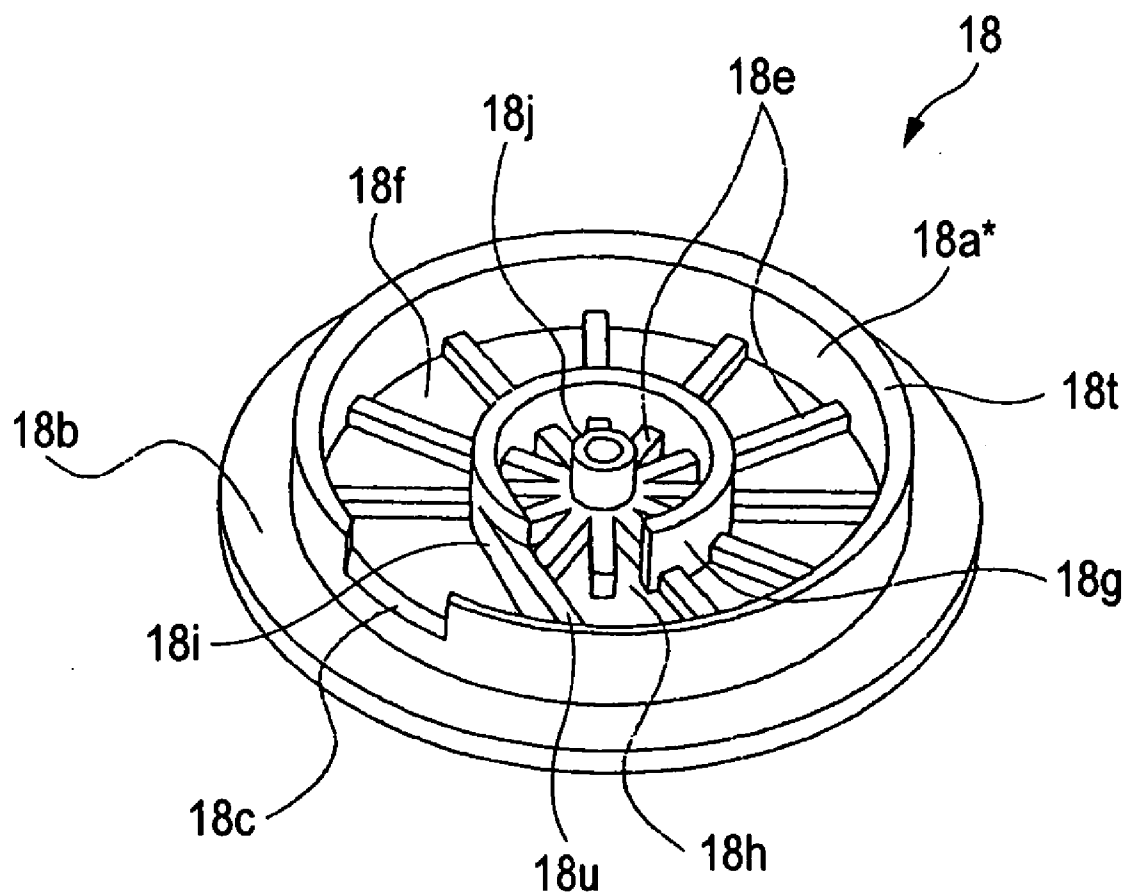


FIG. 6

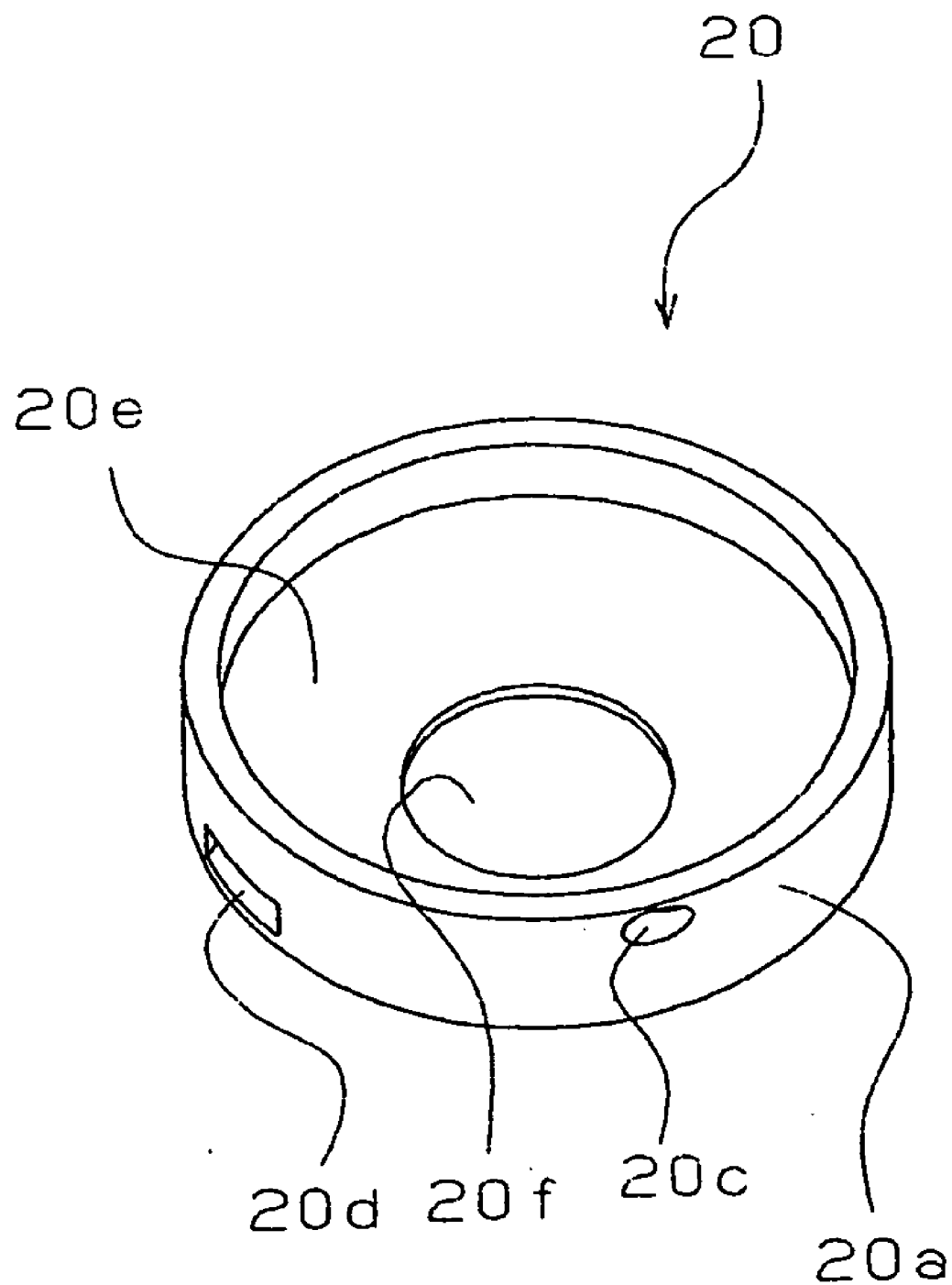


FIG. 7

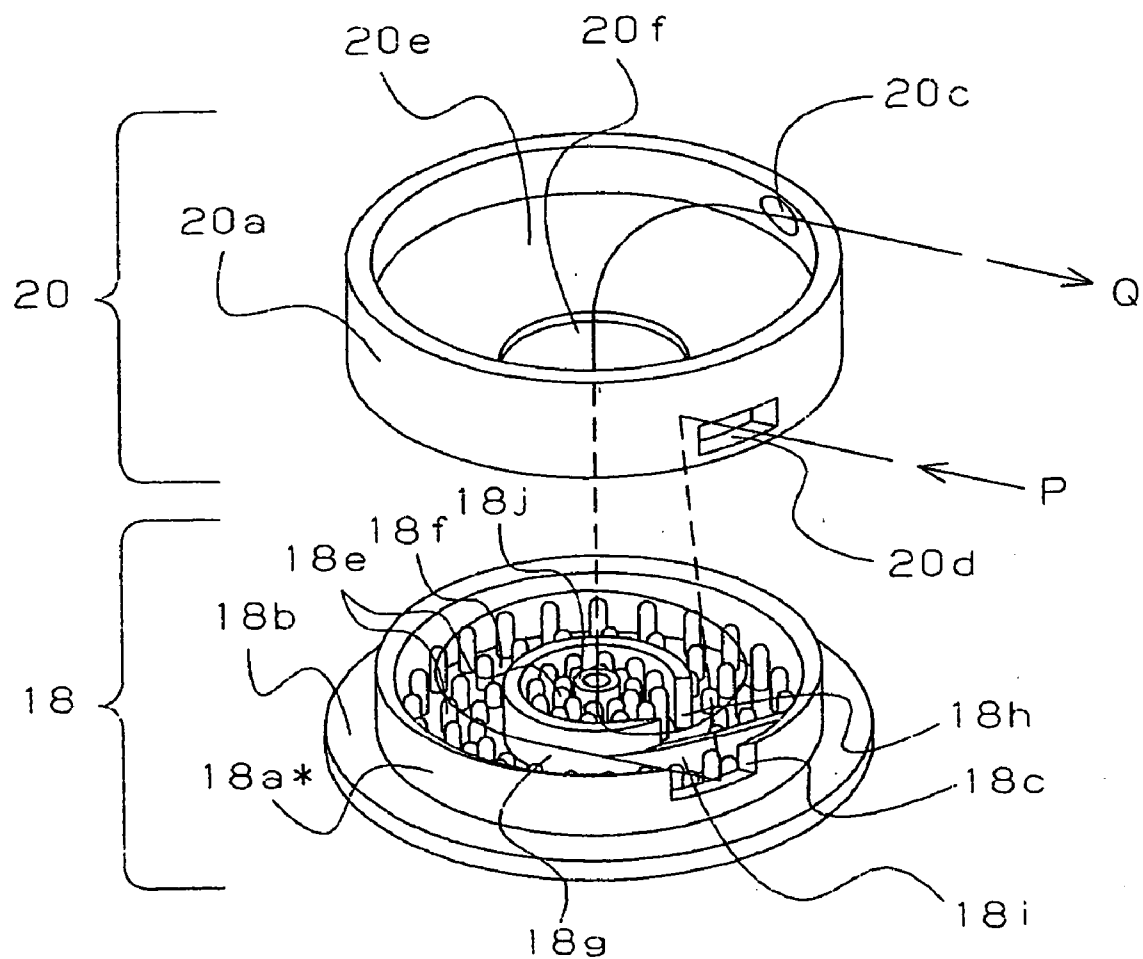


FIG. 9

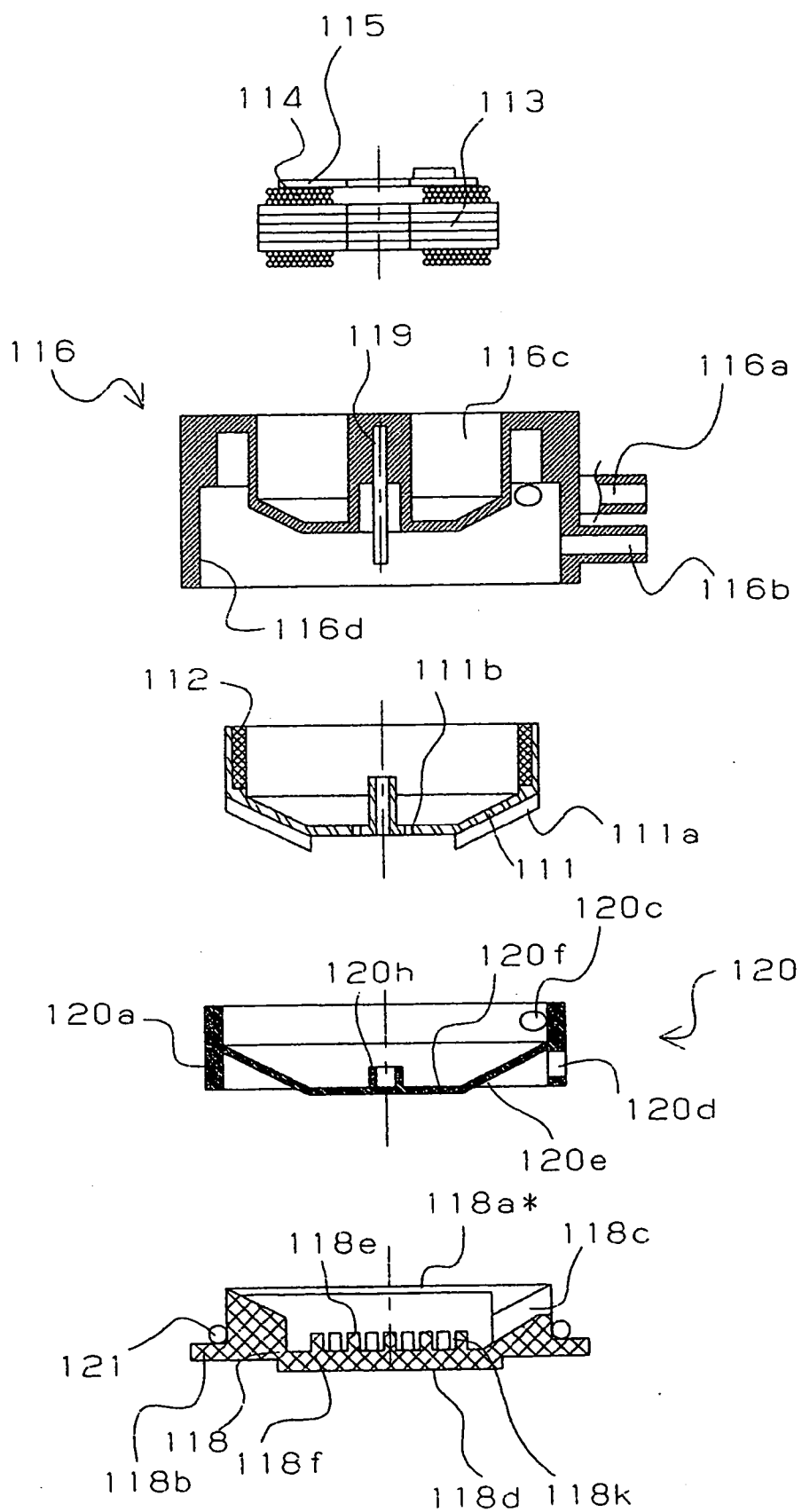


FIG. 10

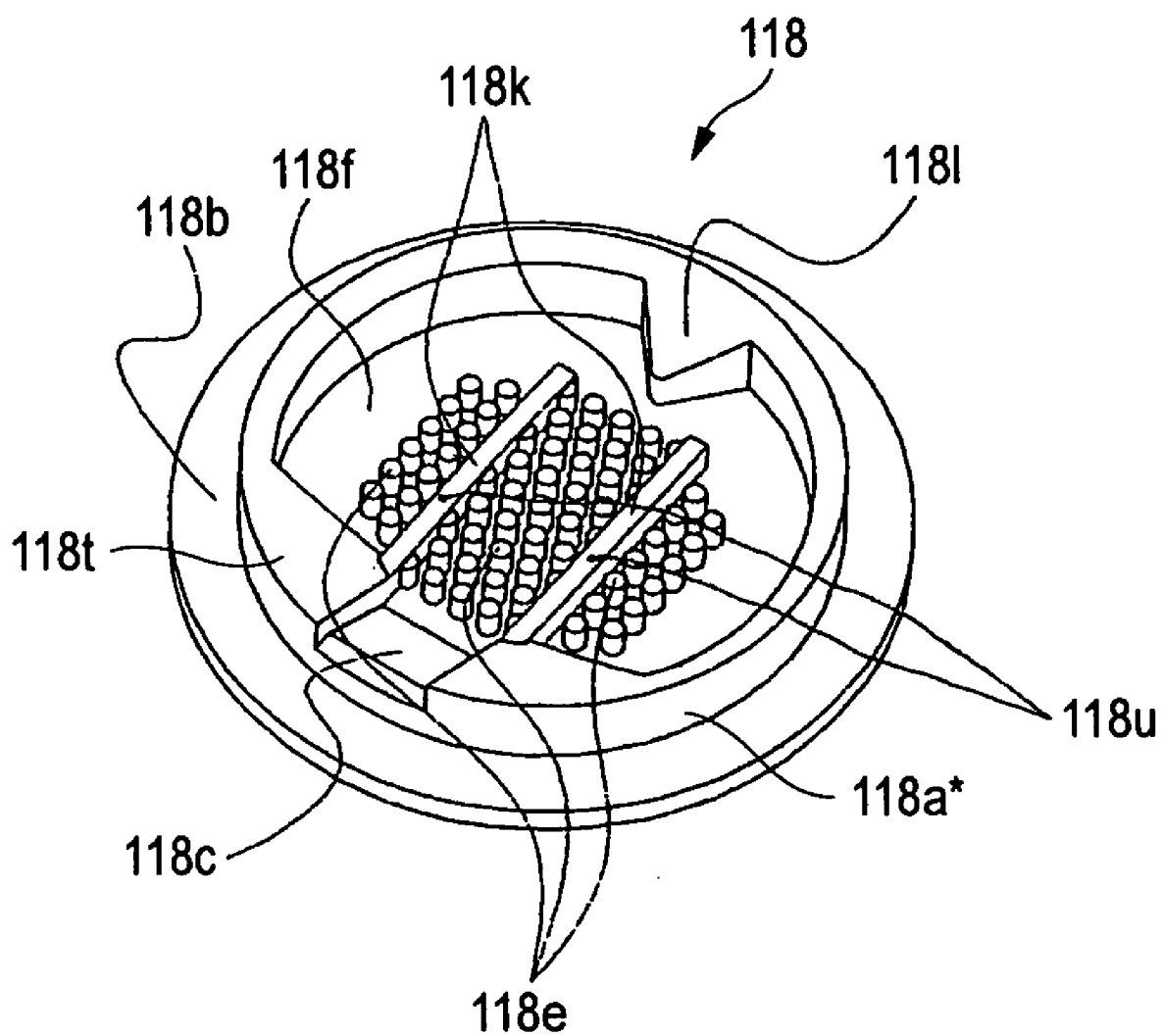


FIG. 11

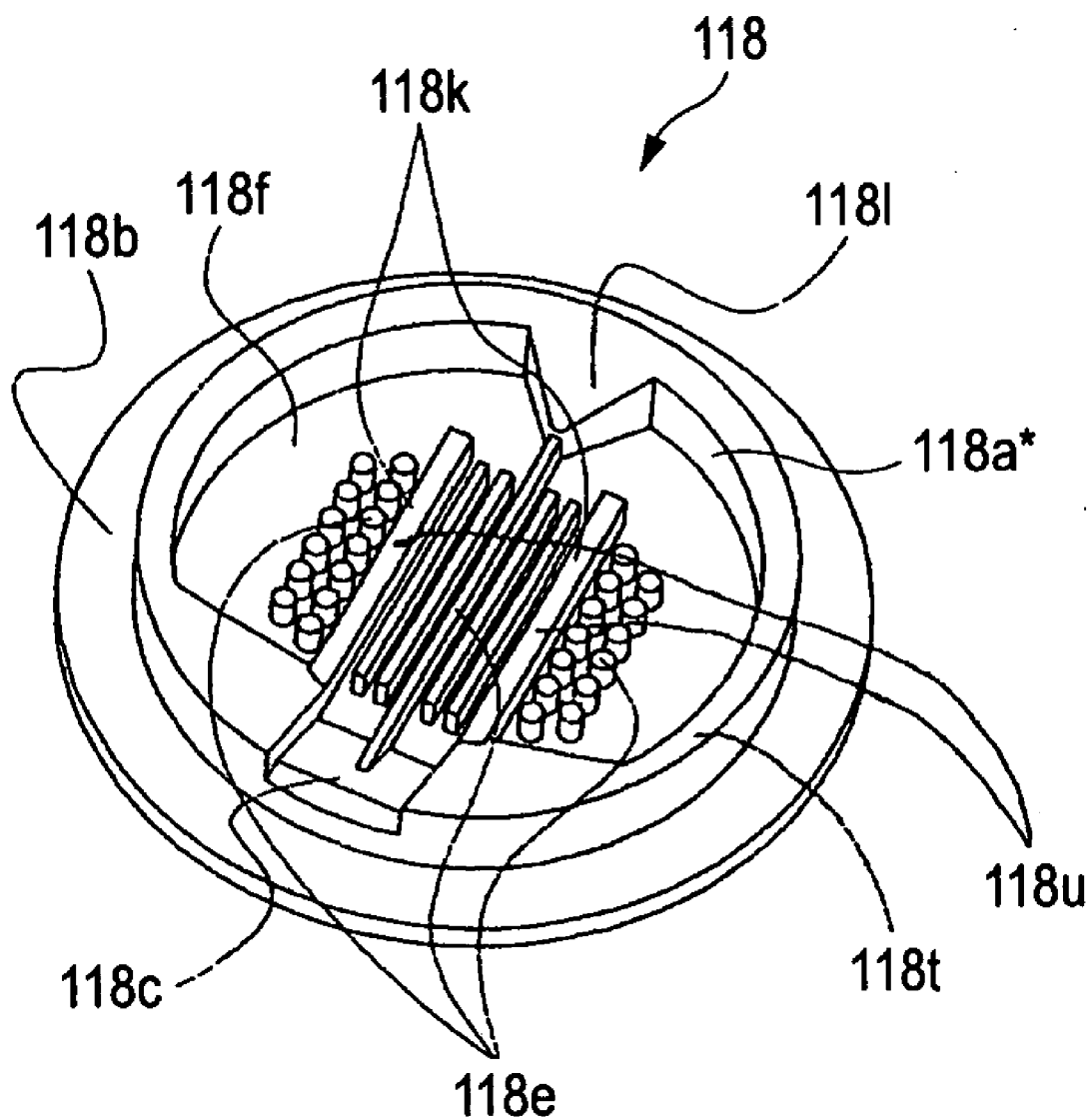


FIG. 12

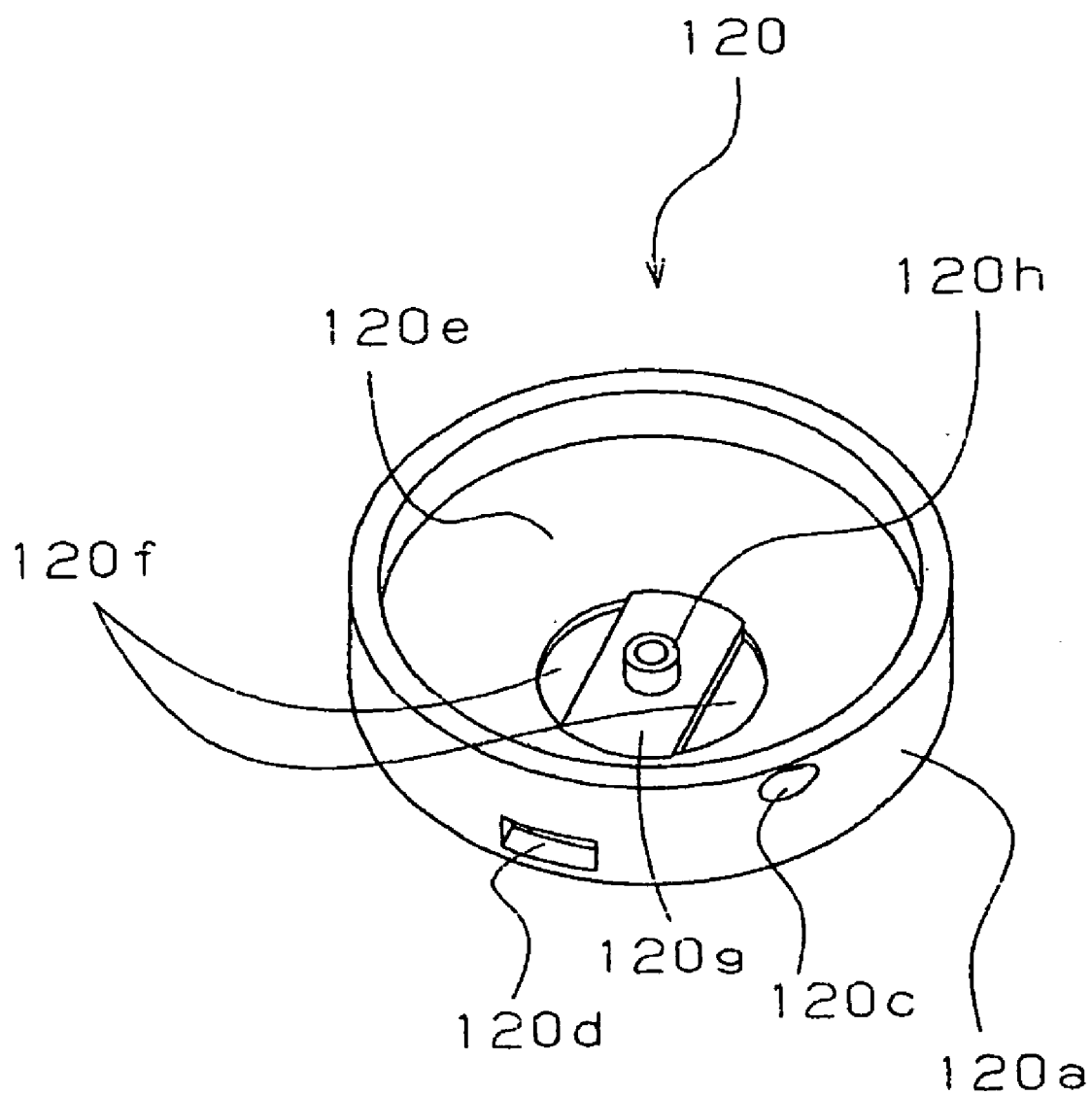


FIG. 15

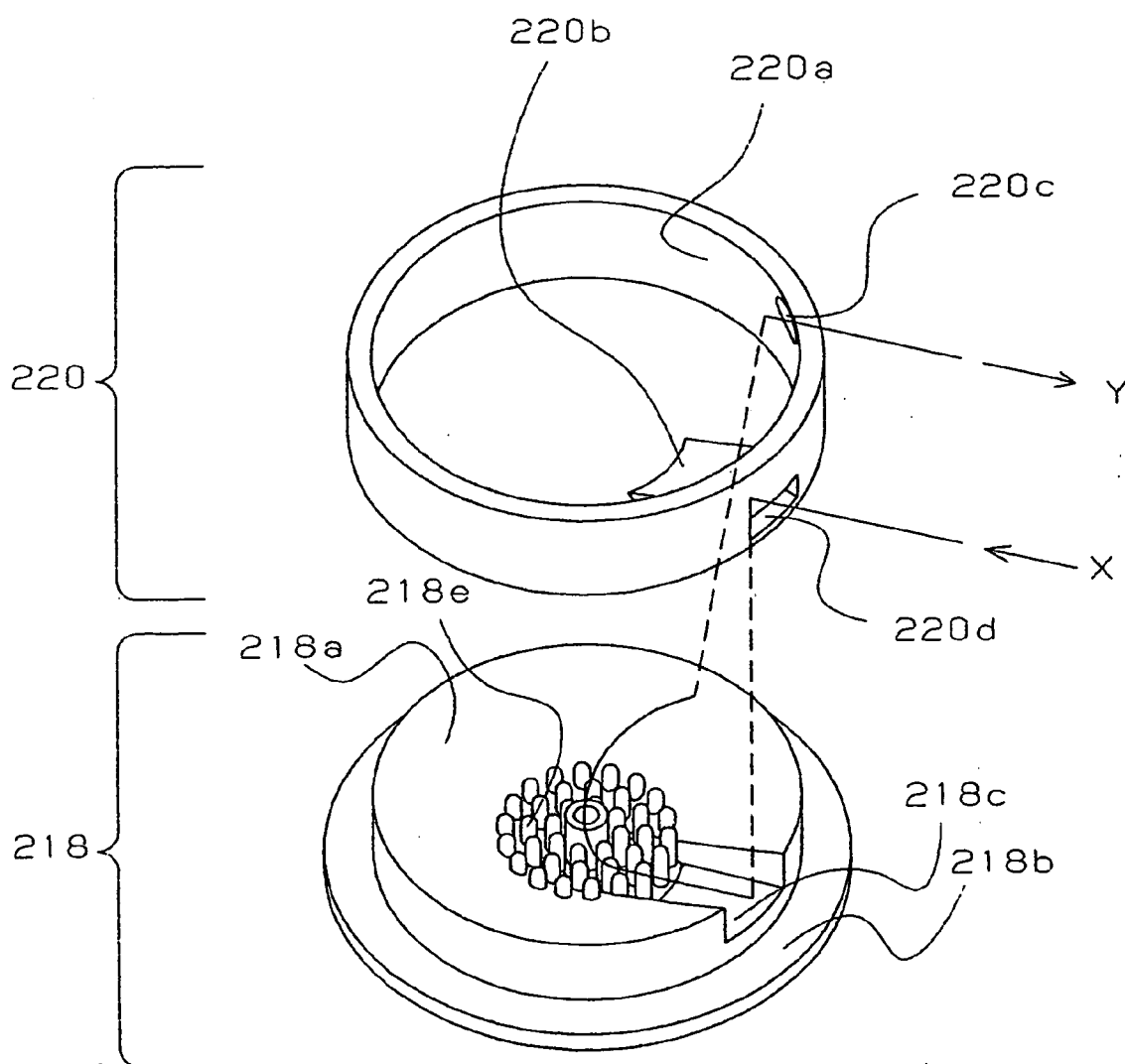


FIG. 16

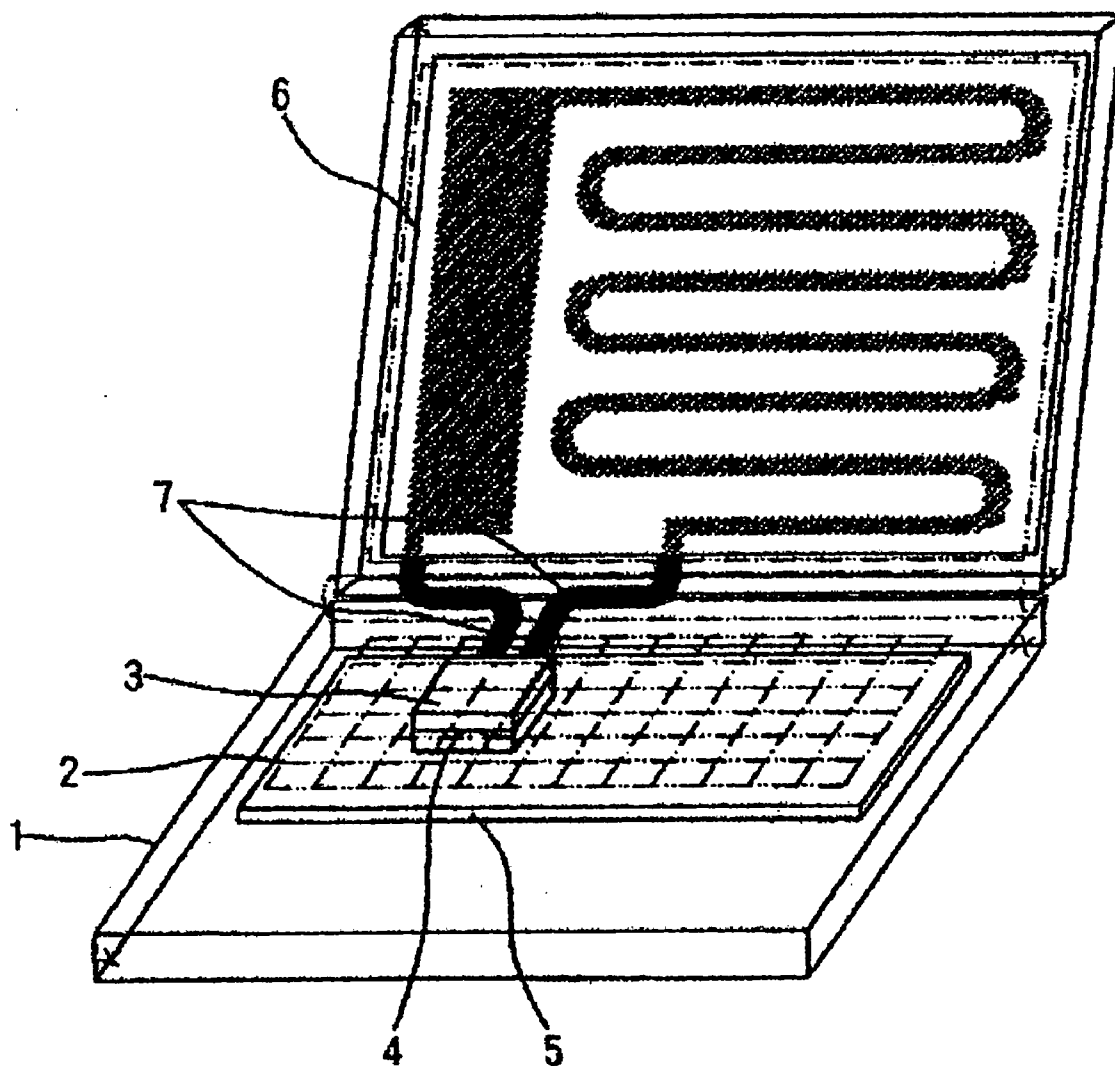


FIG. 17

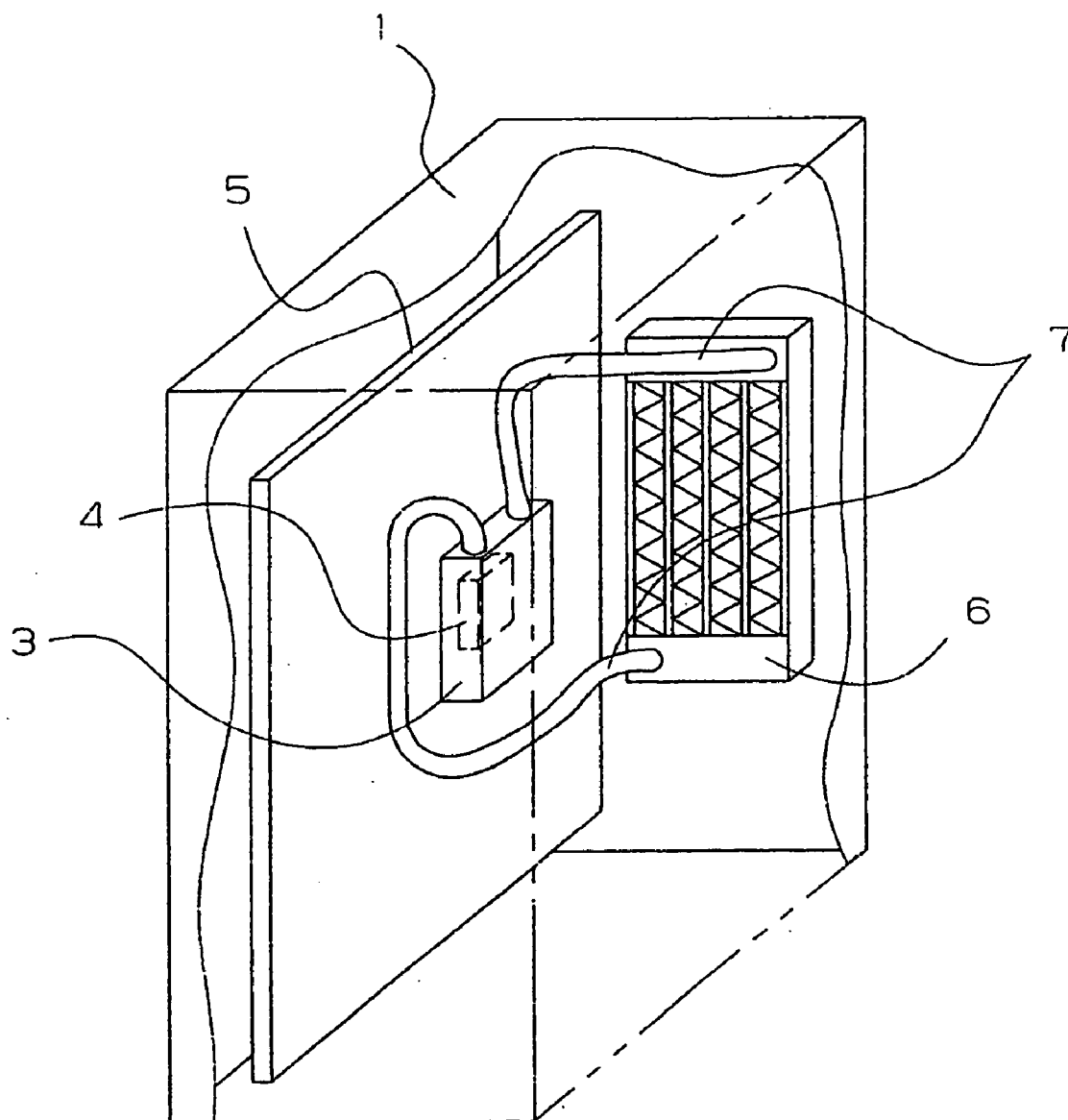
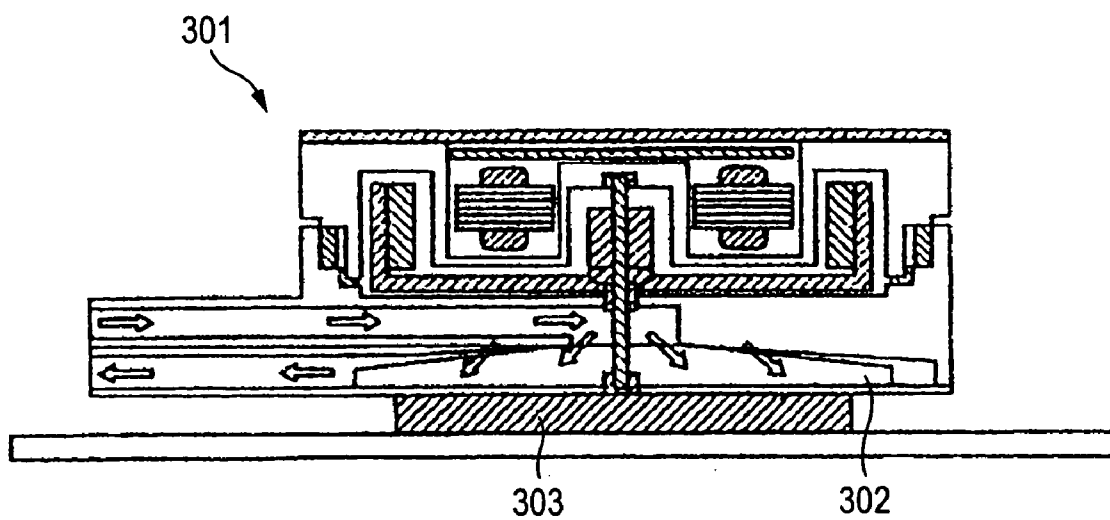


FIG. 18



HEATSINK APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a heatsink apparatus that circulates a coolant to cool heat-generating semiconductor components, including a micro processing unit (hereinafter referred to as an MPU) used in a personal computer and the like, and other electronic components having heat-generating portions.

[0003] 2. Description of Related Art

[0004] Recent electronic devices include highly integrated electronic components and generate high operating clock frequencies, thereby producing a larger amount of heat from the electronic components. Due to the heat increase, temperatures at contact points of the electronic components surpass an operating temperature range, resulting in more than a few malfunctions of the electronic components. It is thus a critical issue to maintain the temperatures of the electronic components within the operating temperature range so that the electronic components function properly.

[0005] Conventional air-cooling using a heatsink alone, however, is insufficient to cool the heat-generating electronic components. Thus, a heatsink apparatus having higher performance and higher efficiency as shown in **FIG. 18**, for instance, is disclosed (Related Art 1). **FIG. 18** shows a cross-sectional view of a cooling module 301 that uses a centrifugal pump.

[Related Art 1] Japanese Patent Laid-Open Publication 2004-134423

[0006] However, the heatsink apparatus disclosed in Related Art 1, in which a coolant flows through the center of an impeller 302 toward a heat-generating component 303, has the following problems: a complex impeller bearing structure declines reliability; low rigidity of the impeller bearing causes noise or declines reliability; and resistance of the coolant running through a small hole at the center of the impeller causes difficulty in ensuring flow rate of the coolant, thus impeding improvement in cooling performance.

[0007] To overcome the above-described problems, a compact heatsink apparatus as shown in **FIG. 14**, for example, is proposed in which a combined heatsink portion and pump circulates a coolant so as to cool a heated electronic component in a highly efficient manner.

[0008] **FIG. 14** is a cross-sectional view of a centrifugal pump of a conventional heatsink apparatus; **FIG. 15** illustrates a flow direction of the coolant in the centrifugal pump of the conventional heatsink apparatus; and **FIGS. 16 and 17** show structures of an electronic device having a heatsink apparatus.

[0009] The structure of the electronic-device having the heatsink apparatus is first described with reference to **FIG. 16**. As shown in **FIG. 16**, the electronic device includes: body 1 of a laptop computer as the electronic device having the heatsink apparatus; keyboard 2 of the laptop computer; centrifugal pump 3 constituting the heatsink apparatus and contacting a heat-generating component for heat exchange; heat-generating electronic component 4 such as an MPU and the like; board 5 mounted with heat-generating electronic

component 4; radiator 6 provided on a rear side of a laptop computer display and dissipating heat of the coolant to the exterior, the heat received from heat-generating electronic component 4; and closed circulation channel 7 connecting centrifugal pump 3 and radiator 6 and circulating the coolant. A description of **FIG. 17**, which shows a desktop computer having the heatsink apparatus, is omitted since the structure of the heatsink apparatus is the same as that in the laptop computer.

[0010] An internal structure of conventional centrifugal pump 3 is described below with reference to **FIGS. 14 and 15**. As shown in **FIGS. 14 and 15**, centrifugal pump 3 includes: open-type impeller 211 of centrifugal pump 3; open-type blades 211a of impeller 211; magnet rotor 212 provided on an inner peripheral surface of impeller 211; stator 213 provided on an inner peripheral side of magnet rotor 212; coil 214 wound around stator 213; circuit board 215 mounted with electric circuits that provide a current to coil 214; upper casing 216; discharge channel 216a formed in upper casing 216; suction channel 216b also formed in upper casing 216; heat-receiving lower casing 218 fitted to upper casing 216 and contacting heat-generating electronic component 4; thick portion 218a; brim 218b touching upper casing 216; recess 218c; contact surface 218d contacting heat-generating electronic component 4; and heat-dissipating fins 218e transferring heat received from heat-generating electronic component 4 to the coolant.

[0011] Centrifugal pump 3 further includes: shaft 219 forming a rotating axis of impeller 211 and fixed to upper casing 216; ring-shaped sealing member 220 fitted to upper casing 216 so as to form pump chamber 217, as also shown in **FIG. 15**; cylindrical portion 220a fitted to a side face of thick portion 218a of lower casing 218; and water channel sealing portion 220b provided between upper casing 216 and lower casing 218 and covering recess 218c so as to form a water channel. As **FIG. 15** shows, discharge connection 220c provided on an upper side of ring-shaped sealing member 220 connects pump chamber 217 and discharge channel 216a; suction connection 220d provided on a lower side of ring-shaped sealing member 220 connects pump chamber 217 and suction channel 216b. Sealing member 221 such as an o-ring seals a portion between upper casing 216 and lower casing 218.

[0012] Functions of centrifugal pump 3 of the heatsink apparatus are described below. The coolant is drawn into suction channel 216b and forced through suction connection 220d. The coolant is then led toward the center of pump chamber 217 by water channel sealing portion 220b and propelled to an outer periphery of pump chamber 217 by rotation of blades 211a. Then, the coolant is forced through discharge connection 220c and discharged from discharge channel 216a. Meanwhile, the heat emitted from heat-generating electronic component 4 is transferred from contact surface 218d to radiating fins 218e and thick portion 218a. The coolant dissipates the heat from surfaces of heat-dissipating fins 218e and thick portion 218a as flowing inside centrifugal pump 3. **FIG. 15** illustrates the flow direction of the coolant in centrifugal pump 3, wherein the coolant enters in a direction of arrow X, runs along a heavy line and discharges in a direction of arrow Y.

[0013] In the heatsink apparatus shown in **FIGS. 14 and 15**, the coolant enters from recess 218c of lower casing 218

and flows on the surface of thick portion **218a**, thereby not required to pass through the center of impeller **211**. The structure thus allows the heatsink apparatus to provide higher reliability and higher cooling performance than the heatsink apparatus disclosed in Related Art 1.

[0014] The conventional heatsink apparatus having combined centrifugal pump **3** reduces its size and provides high heat transfer performance in a central portion of lower casing **218**. However, the conventional heatsink apparatus has low heat transfer efficiency on an outer peripheral side away from the central portion, thus falling short of achieving highly efficient heat transfer across the pump. Providing heat-dissipating fins on the surface of thick portion **218a** can increase the heat transfer efficiency on the outer peripheral side, but also increases a gap between the surface of thick portion **218a** and blades **211a**, which causes a leakage flow of the coolant and thereby degrades pumping capability.

SUMMARY OF THE INVENTION

[0015] The present invention is provided to address the above-described problems. A purpose of the present inventor is to provide a heatsink apparatus that has low thermal resistance on a pump side face and thereby improves overall cooling efficiency and maintains a temperature of a heat-generating electronic component low.

[0016] The present invention relates to a heatsink apparatus having a radiator and a centrifugal pump in a closed circulation channel for circulating a coolant, the centrifugal pump contacting a heat-generating component and releasing heat from the heat-generating component through heat exchange of the coolant therein, the radiator dissipating the heat. The centrifugal pump includes: a first casing provided with a contact surface that contacts the heat-generating component; a second casing fitted to the first casing so as to form a space wherein the coolant flows; a partition wall member provided between the first and second casings so as to form a heat transfer chamber between the partition wall member and the first casing and to form a pump chamber that houses an impeller between the partition wall member and the second casing; a coolant inlet connected to the heat transfer chamber; a coolant outlet connected to the pump chamber; and the heat transfer chamber connected to the pump chamber through a through-hole formed in a central portion of the partition wall member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The present invention is further described in the detailed description which follows, with reference to the noted plurality of drawings by way of non-limiting examples of exemplary embodiments of the present invention, in which like reference numerals represent similar parts throughout the several views of the drawings, and wherein:

[0018] **FIG. 1** is a cross-sectional view of a centrifugal pump in a heatsink apparatus according to a first embodiment of the present invention;

[0019] **FIG. 2** is an exploded cross-sectional view of the centrifugal pump in the heatsink apparatus according to the first embodiment of the present invention;

[0020] **FIG. 3** is a perspective view of a lower casing according to the first embodiment of the present invention;

[0021] **FIG. 4** is a perspective view of the lower casing according to the first embodiment of the present invention;

[0022] **FIG. 5** is a perspective view of the lower casing according to the first embodiment of the present invention;

[0023] **FIG. 6** is a perspective view of a ring-shaped sealing member as a single unit according to the first embodiment of the present invention;

[0024] **FIG. 7** illustrates a flow direction of a coolant in the centrifugal pump according to the first embodiment of the present invention;

[0025] **FIG. 8** is a cross-sectional view of a centrifugal pump in a heatsink apparatus according to a second embodiment of the present invention;

[0026] **FIG. 9** is an exploded cross-sectional view of the centrifugal pump in the heatsink apparatus according to the second embodiment of the present invention;

[0027] **FIG. 10** is a perspective view of a lower casing according to the second embodiment of the present invention;

[0028] **FIG. 11** is a perspective view of the lower casing according to the second embodiment of the present invention;

[0029] **FIG. 12** is a perspective view of a ring-shaped sealing member as a single unit according to the second embodiment of the present invention;

[0030] **FIG. 13** illustrates a flow direction of a coolant in the centrifugal pump according to the second embodiment of the present invention;

[0031] **FIG. 14** is a cross-sectional view of a centrifugal pump in a conventional heatsink apparatus;

[0032] **FIG. 15** illustrates a flow direction of a coolant in the centrifugal pump of the conventional heatsink apparatus;

[0033] **FIG. 16** illustrates a structure of an electronic device having a heatsink;

[0034] **FIG. 17** illustrates a structure of an electronic device having a heatsink; and

[0035] **FIG. 18** is a cross-sectional view of a cooling module that uses a centrifugal pump.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0036] The embodiments of the present invention are explained in the following, in reference to the above-described drawings.

First Embodiment

[0037] A centrifugal pump in a heatsink apparatus according to a first embodiment of the present invention is described below. **FIG. 1** is a cross-sectional view of the centrifugal pump in the heatsink apparatus according to the first embodiment of the present invention; **FIG. 2** is an exploded cross-sectional view of the centrifugal pump in the heatsink apparatus according to the first embodiment of the present invention; **FIGS. 3 to 5** are perspective views of a lower casing according to the first embodiment of the present invention; **FIG. 6** is a perspective view of a ring-

shaped sealing member as a single unit according to the first embodiment of the present invention; and **FIG. 7** illustrates a flow direction of a coolant in the centrifugal pump according to the first embodiment of the present invention. An overall structure of an electronic device having the heatsink apparatus according to the first embodiment is the same as that in the conventional art, thus **FIGS. 16 and 17** are also referred in the first embodiment. Detailed explanations of the figures are as described in the conventional art.

[0038] An internal structure of centrifugal pump **3** is described below with reference to **FIGS. 1 to 7**. Centrifugal pump **3** includes: open-type impeller **11** of centrifugal pump **3**; open-type blades **11a**; small holes **11b** formed near the center of impeller **11**; and magnet rotor **12** attached to an inner peripheral surface of impeller **11**. Impeller **11** and magnet rotor **12** are separately formed in the first embodiment. However, magnet rotor **12** may be integrally formed by magnetizing a portion of impeller **11**, which is made of magnetic material mixed plastics.

[0039] When impeller **11** rotates the coolant, a coolant pressure becomes higher on an outer peripheral side of blades **11a** than on an inner peripheral side of blades **11a** (K in **FIG. 1**). Further, the pressure is substantially the same at an entrance of impeller **11** and on a rear side of impeller **11** connected through small holes **11b**. Therefore, the coolant runs on the rear side of impeller **11** and passes through small holes **11b**, then a small amount of the coolant is refluxed to the entrance. The structure thus reduces a thrust force to impeller **11**, compared to a structure where small holes **11b** are not provided, and thereby smoothens the rotation of impeller **11**. Centrifugal pump **3** of the first embodiment has a thickness of 3 mm to 50 mm, a representative radius of 10 mm to 100 mm, a revolution of 1,000 rpm to 8,000 rpm and a head of 0.5 m to 10 m.

[0040] Centrifugal pump **3** further includes: stator **13** provided on an inner peripheral side of magnet rotor **12**; coil **14** wound around stator **13** to generate a magnetic field in stator **13**; and circuit board **15** mounted with electric circuits that provide a current to coil **14**. It is preferable to layer a plurality of silicon sheets when forming stator **13** so as to minimize eddy-current losses. It is further preferable to use an insulation coated copper wire for coil **14**. A wire diameter and wire turns of coil **14** are optimized based on a power voltage and a space factor. Mounted on circuit board **15** are a hole element that detects a rotating position of magnet rotor **12** and a transistor or a diode that switches a current flow.

[0041] Centrifugal pump **3** further includes: upper casing **16** housing impeller **11**; discharge channel **16a** formed in upper casing **16**; suction channel **16b** formed in upper casing **16**; recess **16c** providing a space to receive magnetic circuits, including stator **13**; and fitting surface **16d** fitted to a ring-shaped sealing member, which will be described later. When forming upper casing **16**, it is preferable to mold plastics such as polyphenylene sulfide (PPS) and polyphenylene ether (PPE), since upper casing **16** has a complex structure and is required to have certain heat resistance. It is not preferable, on the other hand, to form upper casing **16** of metal, since fluctuation in magnetic flux generated by the magnetic circuits such as stator **13** and the like may cause eddy-current losses.

[0042] Centrifugal pump **3** furthermore includes pump chamber **17** and lower casing **18** that contacts heat-gener-

ating electronic component **4** having heat conducting grease and the like (not shown in the figure) therebetween. Lower casing **18** is formed of metallic material having high heat conductance and high heat dissipating performance, such as copper, aluminum and the like, and is processed in casting, forging, machining or a combination of the processing methods. Lower casing **18** fits to upper casing **16** and forms a space wherein the coolant flows, such as pump chamber **17**.

[0043] To efficiently exchange heat received from heat-generating electronic component **4** with the coolant, lower casing **18** has a structure as shown in **FIG. 3**. Lower casing **18** as shown in **FIGS. 3 and 7** includes: base **18f**; ring-shaped thick portion **18a*** formed on base **18f** and having upper side face **18t** slanted at an angle identical to an angle of partition wall **20e** of ring-shaped sealing member **20**, which will be described later; C-shaped cylindrical portion **18g** formed on base **18f** having substantially the same center as impeller **11** and circulating the coolant in the vicinity of through-hole **20f**, which will be described later; cutout **18h** formed in cylindrical portion **18g**; linear guiding plate **18i** standing perpendicularly to base **18f** and extending from an outer peripheral side to an inner peripheral side of lower casing **18** toward cylindrical portion **18g**; brim **18b** touching upper casing **16**; cutout **18c** for taking in the coolant; contact surface **18d** contacting heat-generating electronic component **4**; heat-dissipating fins **18e** having various shapes and transferring the heat received from heat-generating electronic component **4** to the coolant; and thrust receiver **18j** receiving the thrust force from impeller **11**. Guiding plate **18i** has a height to upper side face **18u** facing ring-shaped sealing member **20** lower on the cylindrical portion **18g** side, slanting at an angle identical to the angle of partition wall **20e** of ring-shaped sealing member **20**. In the first embodiment, cylindrical portion **18g** and guiding plate **18i** are formed together with lower casing **18** in order to maximize an area that lower casing **18** contacts the coolant. Due to manufacturing limitations, however, cylindrical portion **18g** and guiding plate **18i** may be formed on a rear side of the ring-shaped sealing member, which will be described later, or formed as separate parts.

[0044] Centrifugal pump **3** of the first embodiment has pin-type heat-dissipating fins **18e** as shown in **FIG. 3**. In lieu of the pin-type fins, plate- or rib-type fins having a circular arc shape arranged in a concentric pattern may be formed as shown in **FIG. 4**. Further, plate- or rib-type fins extending in a radial pattern may be formed as shown in **FIG. 5**.

[0045] Pin-type heat-dissipating fins **18e** as shown in **FIG. 3** maximize an area for heat dissipation and thus transfer the heat most efficiently. Plate- or rib-type heat-dissipating fins **18e** having a circular arc shape as shown in **FIG. 4** do not only increase the area for heat dissipation, but also reduce flow resistance of the coolant. Plate- or rib-type heat-dissipating fins **18e** extending radially as shown in **FIG. 5** reinforce rigidity of lower casing **18**, thus preventing lower casing **18** from being deformed when centrifugal pump **3** is pushed with strong force against heat-generating electronic component **4**, and preventing a gap from developing between heat-generating electronic component **4** and contact surface **18d** due to deformation. Further, pushing heat-generating electronic component **4** with strong force thinly spreads the heat conducting grease (not shown in the figure) applied between heat-generating electronic component **4**

and contact surface **18d**, thereby minimizing thermal resistance of the heat conducting grease and preventing part separation due to vibrations or shocks to a product.

[0046] Heat-dissipating fins **18e** may have a shape other than the above-described shapes. Heat-dissipating fins **18e** may also have a mix of different shapes. A shape of fins inside and outside of cylindrical portion **18g** needs not to be the same; i.e., pin-type heat-dissipating fins **18e** may be disposed outside cylindrical portion **18g** while rib-type heat-dissipating fins **18e** inside cylindrical portion **18g**. Other combinations of shapes are also possible.

[0047] Further to the structure of centrifugal pump **3** of the first embodiment with reference to **FIG. 1**, shaft **19** provided on upper casing **16** rotatably supports impeller **11**. Shaft **19**, made of highly corrosion-resistant material such as stainless, is inserted and molded to upper casing **16** to form one piece. Ring-shaped sealing member **20** fits to upper casing **16** so as to form pump chamber **17**. Sealing member **21**, such as an o-ring, seals a portion between upper casing **16** and lower casing **18** in order to keep the coolant from leaking therefrom. Round heat transfer chamber **22**, provided between ring-shaped sealing member **20**, which will be described later, and lower casing **18**, forms a circulation channel with cylindrical portion **18g** and ring-shaped thick portion **18a*** of lower casing **18**, and connects to through-hole **20f**, which will be described later, of ring-shaped sealing member **20**.

[0048] When forming ring-shaped sealing member **20** having a structure as shown in **FIG. 6**, it is preferable to mold plastics such as polyphenylene sulfide (PPS) and polyphenylene ether (PPE), since, similar to upper casing **16**, ring-shaped sealing member **20** has a complex structure and is required to have certain heat resistance. As **FIG. 6** shows, cylindrical portion **20a** is fitted to a side face of ring-shaped thick portion **18a*** of lower casing **18**; partition wall **20e** is provided having a narrow gap with blades **11a**; through-hole **20f** is formed in a central portion of partition wall **20e**; discharge-connection **20c**, formed on the upper side of ring-shaped sealing member **20**, connects pump chamber **17** and discharge channel **16a**; and suction connection **20d**, provided on the lower side of ring-shaped sealing member **20**, connects round heat transfer chamber **22** and suction channel **16b**.

[0049] In the first embodiment, partition wall **20e** that forms pump chamber **17** is formed together with ring-shaped sealing member **20** to facilitate manufacturing. For ensuring the rigidity of partition wall **20e** or other purposes, however, partition wall **20e** may be formed separately from ring-shaped sealing member **20**. Further, partition wall **20e** has a conic surface in the first embodiment, but may have a flat surface instead. Flat-shaped partition wall **20e** requires blades **11a** to have a flat-shaped end accordingly. However, conic-shaped partition wall **20** lowers a height of round heat transfer chamber **22**, which is located in a central portion of lower casing **18** and has the highest temperature, and thereby locally accelerates a current speed of the coolant in the portion. A high current speed of the coolant reduces a temperature boundary layer, thus improving heat transfer efficiency. Meanwhile, lowering the entire height of round heat transfer chamber **22** increases the flow resistance and reduces the flow rate of the coolant that runs through the heatsink apparatus, thus adversely increasing the thermal

resistance. Conic-shaped partition wall **20e**, however, hardly increases the total flow resistance and thereby improves the heat transfer efficiency.

[0050] Assembly procedures of above-described centrifugal pump **3** are explained below with reference to **FIG. 2**. First, coil **14** is wound around stator **13**, and circuit board **15** mounted with electronic components is attached to stator **13**. The assembled part having stator **13** is then inserted into recess **16c** of upper casing **16**. A filler (not shown in the figure) is injected into recess **16c** and hardened in a temperature-controlled bath and the like. The filler is used to dissipate the heat from the electronic components mounted on circuit board **15** and to keep the coolant from contacting circuit board **15** in case of leakage. It is desirable to use an epoxy potting agent as the filler. Then, impeller **11** is inserted into shaft **19** formed together with upper casing **16**. Ring-shaped sealing member **20** is then inserted into upper casing **16** so that an outer peripheral surface of cylindrical portion **20a** fits to fitting surface **16d**. When ring-shaped sealing member **20** is inserted, suction connection **20d** and suction channel **16b** are set to connect, so are discharge connection **20c** and discharge channel **16a**. Finally, sealing member **21** is set to an outer peripheral surface of ring-shaped thick portion **18a***, and lower casing **18** is fitted and screwed (not shown in the figure) to upper casing **16**. When lower casing **18** is fitted to upper casing **16**, the outer peripheral surface of ring-shaped thick portion **18a*** and an inner peripheral surface of cylindrical portion **20a** are set to fit- and suction connection **20d** and cutout **18c** are set to connect. As upper casing **16** fits to lower casing **18**, a lower surface of partition wall **20e** of ring-shaped sealing member **20** fits to upper side face **18t** of lower casing **18** and upper side face **18u** of guiding plate **18i**. Thereby, ring-shaped sealing member **20** and lower casing **18** form round heat transfer chamber **22**.

[0051] Functions of centrifugal pump **3** in the heatsink apparatus according to the first embodiment are described below. Activating circuit board **15** generates an alternating magnetic field in stator **13**. The magnetic field rotates impeller **11** combined with magnet rotor **12**, thereby providing momentum to the coolant and causing a negative-pressure in the central portion. Then, the coolant is drawn in from suction channel **16b**. The coolant is forced through suction connection **20d** then into round heat transfer chamber **22** provided on an outer peripheral side of cylindrical portion **18g** and between base **18f** and partition wall **20e**. The coolant then circulates on base **18f**. Led by guiding plate **18i**, the coolant is forced through cutout **18h** to inside cylindrical portion **18g**, then through through-hole **20f**. The rotation of blades **11a** propels the coolant to an outer periphery of pump chamber **17**. The coolant is then forced through discharge connection **20c** and discharged from discharge channel **16a**. **FIG. 7** shows the above-described flow direction of the coolant inside centrifugal pump **3**. The coolant enters in a direction of arrow P, runs along a heavy line, then discharges in a direction of arrow Q.

[0052] Providing substantially C-shaped cylindrical portion **18g** so as to allow round heat transfer chamber **22** to work as the circulation channel prevents the coolant that enters centrifugal pump **3** from being directly drawn in through-hole **20f**, thus allowing the coolant to contact a larger area of lower casing **18**. Further, providing guiding plate **18i** prevents the coolant that enters centrifugal pump **3**

from repeatedly circulating on base **18f**; thus smoothly directing the coolant to through-hole **20f** before turning full circle on base **18f**.

[0053] Lower casing **18** meanwhile receives on contact surface **18d** the heat emitted from heat-generating electronic component **4**. Unlike lower casing **218** in the conventional heatsink apparatus formed itself of a thick portion, lower casing **18** of the first embodiment has base **18f** having a flat shape even on the outer peripheral side of lower casing **18**. Lower casing **18** of the first embodiment thereby allows the heat to transfer extensively on a short heat transfer path inside lower casing **18** and to reach surfaces of heat-dissipating fins **18e**, base **18f** and cylindrical portion **18g**. Since the heat transfer path is short, the thermal resistance is low during the transfer. Thus, surface temperatures of heat-dissipating fins **18e**, base **18f** and cylindrical portion **18g** approach a temperature of heat-generating electronic component **4**.

[0054] As flowing into, circulating on and flowing out from base **18f** of round heat transfer chamber **22**, the coolant contacts at a high speed the surfaces of heat-dissipating fins **18e**, base **18f** and cylindrical portion **18g** that have high temperatures after receiving the heat. Thereby, a temperature boundary layer forms thin and the coolant efficiently receives the heat from lower casing **18**. The conventional heatsink apparatus, which has blades **211a** proximate to a surface of thick portion **218a** (refer to FIG. 14), does not allow forming of fins thereon to expand the surface area, though forming of dimples at best. Unlike lower casing **218** as shown in FIG. 14, which has pump chamber **217** on an outer peripheral side of lower casing **218** and substantially the same curved surface as a rotating surface of blades **211a**, lower casing **18** of the first embodiment is able to have large heat-dissipating fins **18e** on the outer peripheral side of lower casing **18**. Lower casing **18** of the first embodiment thereby significantly increases an area contacting the coolant and greatly reduces a weight of centrifugal pump **3**.

[0055] In the centrifugal pump of the conventional heat-sink apparatus, the surface of thick portion **218a** of lower casing **218** provides two functions as shown in FIG. 14: a function to transfer the heat to the coolant and a function to form a wall of pump chamber **217**. In the first embodiment, wherein partition wall **20e** is provided between impeller **11** and lower casing **18**, the function to transfer the heat to the coolant is provided to the surfaces of base **18f** and heat-dissipating fins **18e** of lower casing **18**, and the function to form pump chamber **17** to partition wall **20e** of ring-shaped sealing member **20**. Thereby, the heatsink apparatus of the first embodiment enjoys highly efficient heat transfer performance, without negatively affecting pumping performance.

[0056] According to the first embodiment of the present invention as described above, integrating the heatsink portion that receives the heat from heat-generating electronic component **4** and the pump provides high flexibility in placing the heatsink apparatus in a body of a small personal computer and the like. Further, the structure described above allows the coolant to contact lower casing **18** on the short heat transfer path from heat-generating electronic component **4**, on the outer periphery of lower casing **18** as well as in the central portion. Thus, the thermal resistance is kept low not only in the central portion, but also on the outer

peripheral side. The overall cooling efficiency is thereby increased and the temperature of heat-generating electronic component **4** is maintained low.

[0057] As the coolant, an antifreeze solution is suitable, including an ethylene glycol solution and a propylene glycol solution. Further, it is desirable to add an anti-corrosion additive since copper or the like is used as lower casing material.

[0058] Radiator **6** as shown in FIGS. 16 and 17 is made of material having high heat conductance and high heat dissipating performance, such as lamellar material of copper and aluminum, and is integrally provided with a coolant channel and a reserve tank therein. The reserve tank may be formed separately from radiator **6**. Further, a fan may be provided to blow air against radiator **6** to accelerate the cooling efficiency. Circulation channel **7** is made of a flexible rubber tube having low gas permeability, such as a butyl rubber tube, so as to ensure flexibility in piping layout.

Second Embodiment

[0059] A centrifugal pump in a heatsink apparatus according to a second embodiment of the present invention is described below. FIG. 8 is a cross-sectional view of the centrifugal pump in the heatsink apparatus according to the second embodiment of the present invention; FIG. 9 is an exploded cross-sectional view of the centrifugal pump in the heatsink apparatus according to the second embodiment of the present invention; FIGS. 10 and 11 are perspective views of a lower casing according to the second embodiment of the present invention; FIG. 12 is a perspective view of a ring-shaped sealing member as a single unit according to the second embodiment of the present invention; and FIG. 13 illustrates a flow direction of a coolant in the centrifugal pump according to the second embodiment of the present invention. An overall structure of an electronic device having the heatsink apparatus according to the second embodiment is the same as that in the conventional art, thus FIGS. 16 and 17 are also referred in the second embodiment. Detailed explanations of the figures are as given in the conventional art.

[0060] An internal structure of centrifugal pump **3** is described below with reference to FIGS. 8 to 13. Centrifugal pump **3** includes: open-type impeller **111** of centrifugal pump **3**; open-type blades **111a**; small holes **111b** formed near the center of impeller **111**; and magnet rotor **112** attached to an inner peripheral surface of impeller **111**. Impeller **111** and magnet rotor **112** are separately formed in the second embodiment. However, magnet rotor **112** may be integrally formed by magnetizing a portion of impeller **111**, which is made of magnetic material mixed plastics.

[0061] When impeller **111** rotates the coolant, a coolant pressure becomes higher on an outer peripheral side of blades **111a** than on an inner peripheral side of blades **111a** (L in FIG. 8). Further, the pressure is substantially the same at an entrance of impeller **111** and on a rear side of impeller **111** connected through small holes **111b**. Therefore, the coolant runs on the rear side of impeller **111** and passes through small holes **111b**, then a small amount of the coolant is refluxed to the entrance. The structure thus reduces a thrust force to impeller **111**, compared to a structure where small holes **111b** are not provided, and thereby smoothens the rotation of impeller **111**. Centrifugal pump **3** of the

second embodiment has a thickness of 3 mm to 50 mm, a representative radius of 10 mm to 100 mm, a revolution of 1,000 rpm to 8,000 rpm and a head of 0.5 m to 10 m.

[0062] Centrifugal pump 3 further includes: stator 113 provided on an inner peripheral side of magnet rotor 112; coil 114 wound around stator 113 to generate a magnetic field in stator 113; and circuit board 115 mounted with electric circuits that provide a current to coil 114. It is preferable to layer a plurality of silicon sheets when forming stator 113 so as to minimize eddy-current losses. It is further preferable to use an insulation coated copper wire for coil 114. A wire diameter and wire turns of coil 114 are optimized based on a power voltage and a space factor. Mounted on circuit board 115 are a hole element that detects a rotating position of magnet rotor 112 and a transistor or a diode that switches a current flow.

[0063] Centrifugal pump 3 further includes: upper casing 116 housing impeller 111; discharge channel 116a formed in upper casing 116; suction channel 116b formed in upper casing 116; recess 116c providing a space to receive magnetic circuits, including stator 113; and fitting surface 116d fitted to a ring-shaped sealing member, which will be described later. When forming upper casing 116, it is preferable to mold plastics such as polyphenylene sulfide (PPS) and polyphenylene ether (PPE), since upper casing 116 has a complex structure and is required to have certain heat resistance. It is not preferable, on the other hand, to form upper casing 116 of metal, since fluctuation in magnetic flux generated by the magnetic circuits such as stator 113 and the like may cause eddy-current losses.

[0064] Centrifugal pump 3 furthermore includes: pump chamber 117 and lower casing 118 that contacts heat-generating electronic component 4 having heat conducting grease and the like (not shown in the figure) therebetween. Lower casing 118 is formed of metallic material having high heat conductance and high heat dissipating performance, such as copper, aluminum and the like, and is processed in casting, forging, machining or a combination of the processing methods. Lower casing 118 fits to upper casing 116 and forms a space wherein the coolant flows, such as pump chamber 117.

[0065] To efficiently exchange heat received from heat-generating electronic component 4 with the coolant, lower casing 118 has a structure as shown in FIG. 10. Lower casing 118 includes: brim 118b touching upper casing 116; recess 118c for taking in the coolant; contact surface 118d contacting heat-generating electronic component 4; heat-dissipating fins 118e transferring the heat received from heat-generating electronic component 4 to the coolant, similar to those in the conventional heatsink apparatus, and expanding an area contacting the coolant so as to facilitate heat transfer; base 118f; ring-shaped thick portion 118a* formed on base 118f and having upper side face 118f slanted at an angle identical to an angle of partition wall 120e of ring-shaped sealing member 120, which will be described later; and guiding portions 118k provided standing substantially perpendicularly to base 118f, for directing the coolant entering onto lower casing 118 so that the coolant runs through a central portion of a suction heat transfer chamber, which will be described later, provided on base 118f.

[0066] In the second embodiment, guiding portions 118k are formed together with lower casing 118 in order to

maximize an area that lower casing 118 contacts the coolant. Due to manufacturing limitations, however, guiding portions 118k may be formed on a rear side of ring-shaped sealing member 120, which will be described later, or formed as separate parts. Also in the second embodiment, flow separation wall 118f is provided on ring-shaped thick portion 118a* facing an inflow direction, so as to separate an incoming flow from guiding portions 118k into two directions in round heat transfer chamber 122, which will be described later.

[0067] Centrifugal pump 3 of the second embodiment has pin-type heat-dissipating fins 118e as shown in FIG. 10. In lieu of the pin-type fins, a combination of the pin-type fins and plate- or rib-type fins may be formed as shown in FIG. 11. One of the plate- and rib-type fins may also be formed.

[0068] Pin-type heat-dissipating fins 118e as shown in FIG. 10 maximize an area for heat dissipation and thus transfer the heat most efficiently. Heat-dissipating fins 118e having the combination of the pin-type and the plate- or rib-type as shown in FIG. 11 do not only increase the area for heat dissipation, but also reduce flow resistance of the coolant. Further, heat-dissipating fins 118e having the combination of the pin-type and the plate- or rib-type reinforce rigidity of lower casing 118, thus preventing lower casing 118 from being deformed when centrifugal pump 3 is pushed with strong force against heat-generating electronic component 4, and preventing a gap from developing between heat-generating electronic component 4 and contact surface 118d due to deformation. Furthermore, pushing heat-generating electronic component 4 with strong force thinly spreads the heat conducting grease (not shown in the figure) applied between heat-generating electronic component 4 and contact surface 118d, thereby minimizing thermal resistance of the heat conducting grease and preventing part separation due to vibrations or shocks to a product.

[0069] Heat-dissipating fins 118e may have a shape other than the pin-type, the plate-type and the rib-type. The description above, which relates to heat-dissipating fins 118e provided between guiding portions 118k, also applies to heat-dissipating fins 118e provided outside guiding portions 118k. Heat-dissipating fins 118e outside guiding portions 118k may be the pin-type, the plate-type, the rib-type, other type or a mix of the types.

[0070] Further to the structure of centrifugal pump 3 of the second embodiment with reference to FIG. 8, shaft 119 provided on upper casing 116 rotatably supports impeller 111. Shaft 119, made of highly corrosion-resistant material such as stainless, is inserted and molded to upper casing 116 to form one piece. Ring-shaped sealing member 120 fits to upper casing 116 so as to form pump chamber 117. Sealing member 121, such as an o-ring, seals a portion between upper casing 116 and lower casing 118 in order to keep the coolant from leaking therefrom. Round heat transfer chamber 122, provided between ring-shaped sealing member 120 and lower casing 118 and formed by guiding portions 118k and ring-shaped thick portion 118a* of lower casing 118, connects to two through-holes 120f, which will be described later, of ring-shaped sealing member 120. Heat transfer guiding channel 123 is sandwiched by a pair of guiding portions 118k and formed between lower casing 118 and top panel 120g, which will be described later.

[0071] When forming ring-shaped sealing member 120 having a structure as shown in FIG. 12, it is preferable to

mold plastics such as polyphenylene sulfide (PPS) and polyphenylene ether (PPE), since, similar to upper casing 116, ring-shaped sealing member 120 has a complex structure and is required to have certain heat resistance. As FIG. 12 shows, cylindrical portion 120a is fitted to a side face of ring-shaped thick portion 118a* of lower casing 118; partition wall 120e is provided having a narrow gap with blades 111a; top panel 120g closes an upper part of guiding portions 118k and forms heat transfer guiding channel 123 that directs the coolant to round heat transfer chamber 122; two half-moon-shaped through-holes 120f are formed on both sides of top panel 120g; thrust receiver 120h receives the thrust force from impeller 111; discharge connection 120c, formed on the upper side of ring-shaped sealing member 120, connects pump chamber 117 and discharge channel 116a; and suction connection 120d, provided on the lower side of ring-shaped sealing member 120, connects round heat transfer chamber 122 and suction channel 116b. Heat transfer guiding channel 123 and round heat transfer chamber 122 as a whole form the suction heat transfer chamber of the present invention, and the pair of guiding portions 118k form a partition member of the present invention.

[0072] In the second embodiment, partition wall 120e that forms pump chamber 117 is formed together with ring-shaped sealing member 120 to facilitate manufacturing. For ensuring the rigidity of partition wall 120e or other purposes, however, partition wall 120e may be formed separately from ring-shaped sealing member 120. Further, partition wall 120e has a conic surface in the second embodiment, but may have a flat surface instead. Flat-shaped partition wall 120e requires blades 111a to have a flat-shaped end accordingly. However, conic-shaped partition wall 120e lowers a height of round heat transfer chamber 122, which is located in a central portion of lower casing 118 and has the highest temperature, and thereby locally accelerates a current speed of the coolant in the portion. A high current speed of the coolant reduces a temperature boundary layer, thus improving heat transfer efficiency. Meanwhile, lowering the entire height of round heat transfer chamber 122 increases the flow resistance and reduces the flow rate of the coolant that runs through the heatsink apparatus, thus adversely increasing the thermal resistance. Conic-shaped partition wall 120e, however, hardly increases the total flow resistance and thereby improves the heat transfer efficiency.

[0073] Assembly procedures of above-described centrifugal pump 3 are explained below with reference to FIG. 9. First, coil 114 is wound around stator 113, and circuit board 115 mounted with electronic components is attached to stator 113. The assembled part having stator 113 is then inserted into recess 116c of upper casing 116. A filler (not shown in the figure) is injected into recess 116c and hardened in a temperature-controlled bath and the like. The filler is used to dissipate the heat from the electronic components mounted on circuit board 115 and to keep the coolant from contacting circuit board 115 in case of leakage. It is desirable to use an epoxy potting agent as the filler. Then, impeller 111 is inserted into shaft 119 formed together with upper casing 116. Ring-shaped sealing member 120 is then inserted into upper casing 116 so that an outer peripheral surface of cylindrical portion 120a fits to fitting surface 116d. When ring-shaped sealing member 120 is inserted, suction connection 120d and suction channel 116b are set to connect, so are discharge connection 120c and discharge channel 116a. Finally, sealing member 121 is set to an outer peripheral

surface of ring-shaped thick portion 118a*, and lower casing 118 is fitted and screwed (not shown in the figure) to upper casing 116. When lower casing 118 is fitted to upper casing 116, the outer peripheral surface of ring-shaped thick portion 118a* and an inner peripheral surface of cylindrical portion 120a are set to fit, and suction connection 120d and recess 118c are set to connect. As upper casing 116 fits to lower casing 118, a lower surface of partition wall 120e of ring-shaped sealing member 120 fits to upper side face 118t of lower casing 118, and a lower surface of top panel 120g of ring-shaped sealing member 120 fits to upper side face 118u of guiding portions 118k. Thereby, ring-shaped sealing member 120 and lower casing 118 form round heat transfer chamber 122.

[0074] Functions of centrifugal pump 3 in the heatsink apparatus according to the second embodiment are described below. Activating circuit board 115 generates an alternating magnetic field in stator 113. The magnetic field rotates impeller 111 combined with magnet rotor 112, thereby providing momentum to the coolant and causing a negative-pressure in the central portion. Then, the coolant is drawn in from suction channel 116b. The coolant is forced through suction connection 120d then to heat transfer guiding channel 123 formed between lower casing 118 and top panel 120g. The entered coolant efficiently dissipates the heat from high-temperature base 118f located directly above heat-generating electronic component 4.

[0075] Then the coolant reaches an end of base 118f and is separated into two directions to right and left. The two flows of the separated coolant respectively circulate in round heat transfer chamber 122 provided between guiding portions 118k and ring-shaped thick portion 118a*. The negative-pressure in the central portion of impeller 111 draws in the coolant again to the central portion of base 118f and forces the coolant through two through-holes 120f. During the process, the coolant dissipates the heat that travels a short distance from heat-generating electronic component 4 to base 118f.

[0076] Although the coolant is separated into two directions at the flow separation wall as reaching the end of base 118f in the second embodiment, the coolant may flow in one direction. Separating the coolant into two directions, however, reduces the flow resistance and evenly cools an outer periphery of lower casing 118. Finally, the coolant provided with the momentum by the rotation of impeller 111 is propelled to an outer periphery of pump chamber 117, forced through discharge connection 120c and then discharged from discharge channel 116a. FIG. 13 shows the above-described flow direction of the coolant inside centrifugal pump 3. The coolant enters in a direction of arrow R, runs along a heavy line, then discharges in a direction of arrow S.

[0077] Unlike the conventional heatsink apparatus wherein the coolant is drawn straight into impeller 211, centrifugal pump 3 of the second embodiment, provided with guiding portions 118k and top panel 120g that form heat transfer guiding channel 123, directs the entered coolant linearly from end to end in the central portion of lower casing 118 with no leakage to other portions. Thereby, the coolant contacts at a high speed a wide surface area of the central portion of lower casing 118 that has the highest temperature. Further, unlike the conventional heatsink apparatus wherein the coolant stagnates in pump chamber 217,

centrifugal pump 3 of the second embodiment has no adverse impact on cooling efficiency.

[0078] Furthermore, unlike lower casing 218 in the conventional heatsink apparatus formed itself of a thick portion, lower casing 118 of the second embodiment, provided with round heat transfer chamber 122 surrounding heat transfer guiding channel 123, has flat base 118f. Lower casing 118 of the second embodiment thereby allows the heat to transfer extensively on a short path inside lower casing 118 and to reach surfaces of heat-dissipating fins 118e and base 118f. Since the heat transfer path is short, the thermal resistance is low during the transfer. Thus, surface temperatures of heat-dissipating fins 118e and base 118f approach a temperature of heat-generating electronic component 4.

[0079] As flowing into the central portion of lower casing 118 and circulating in and flowing out from round heat transfer chamber 122 of lower casing 118, the coolant contacts at a high speed the surfaces of heat-dissipating fins 118e and base 118f that have high temperatures after receiving the heat. Thereby, a temperature boundary layer forms thin and the coolant efficiently receives the heat from lower casing 118. The conventional heatsink apparatus, which has blades 211a proximate to a surface of thick portion 218a (refer to FIG. 14), does not allow forming of fins thereon to expand the surface area, though forming of dimples at best. Unlike lower casing 218 as shown in FIG. 14, which has thick portion 218a, lower casing 118 of the second embodiment is able to have large heat-dissipating fins 118e on the outer peripheral side of lower casing 118, thereby significantly increasing an area contacting the coolant.

[0080] In the centrifugal pump of the conventional heatsink apparatus, the surface of thick portion 218a of lower casing 218 provides two functions as shown in FIG. 15: a function to transfer the heat to the coolant and a function to form a wall of pump chamber 217. In the second embodiment, wherein partition wall 120e is provided between impeller 111 and lower casing 118, the function to transfer the heat to the coolant is provided to the surfaces of base 118f and heat-dissipating fins 118e of lower casing 118, and the function to form the wall of pump chamber 117 to partition wall 120e of ring-shaped sealing member 120. Thereby, the heatsink apparatus of the second embodiment enjoys highly efficient heat performance, without negatively affecting pumping performance.

[0081] According to the second embodiment of the present invention as described above, integrating the heatsink portion that receives the heat from heat-generating electronic component 4 and the pump provides high flexibility in placing the heatsink apparatus in a body of a small personal computer and the like. Further, the structure described above allows the coolant to contact the entire central portion of the lower casing at a high speed and to contact the lower casing on a short heat transfer path from the heat-generating electronic component in the round heat transfer chamber on the outer periphery of the lower casing. Thus, the thermal resistance is kept low both in the central portion and on the outer periphery, thereby maintaining the temperature of the heat-generating electronic component low.

[0082] As the coolant, an antifreeze solution is suitable, including an ethylene glycol solution and a propylene glycol solution. Further, it is desirable to add an anti-corrosion additive since copper or the like is used as lower casing material.

[0083] Radiator 6 as shown in FIGS. 16 and 17 is formed of material having high heat conductance and high heat dissipating performance, such as lamellar material of copper and aluminum, and is integrally provided with a coolant channel and a reserve tank thereinside. The reserve tank may be formed separately from radiator 6. Further, a fan may be provided to blow air against radiator 6 to accelerate the cooling efficiency. Circulation channel 7 is made of a flexible rubber tube having low gas permeability, such as a butyl rubber tube, so as to ensure flexibility in piping layout.

[0084] It is noted that the foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention. While the present invention has been described with reference to exemplary embodiments, it is understood that the words which have been used herein are words of description and illustration, rather than words of limitation. Changes may be made, within the purview of the appended claims, as presently stated and as amended, without departing from the scope and spirit of the present invention in its aspects. Although the present invention has been described herein with reference to particular structures, materials and embodiments, the present invention is not intended to be limited to the particulars disclosed herein; rather, the present invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims.

[0085] The present invention is not limited to the above described embodiments, and various variations and modifications may be possible without departing from the scope of the present invention.

[0086] This application is based on the Japanese Patent Applications No. 2004-376062 and No. 2004-376063 filed on Dec. 27, 2004, entire content of which is expressly incorporated by reference herein.

What is claimed is:

1. A heatsink apparatus having a radiator and a centrifugal pump in a closed circulation channel for circulating a coolant, the centrifugal pump contacting a heat-generating component and releasing heat from the heat-generating component through heat exchange of the coolant therein, the radiator dissipating the heat, the centrifugal pump comprising:

- a first casing provided with a contact surface that contacts the heat-generating component;
- a second casing fitted to be first casing so as to form a space wherein the coolant flows;
- a partition wall member provided between the first and second casings so as to form a heat transfer chamber between the partition wall member and the first casing and to form a pump chamber that houses an impeller between the partition wall member and the second casing;
- a coolant inlet connected to the heat transfer chamber;
- a coolant outlet connected to the pump chamber; and
- the heat transfer chamber connected to the pump chamber through a through-hole formed in a central portion of the partition wall member.

2. The heatsink apparatus according to claim 1, further comprising a guiding member provided between the first casing and the partition wall member of the heat transfer chamber so as to form a flow channel of the coolant.

3. The heatsink apparatus according to claim 2, wherein the guiding member comprises:

a C-shaped cylindrical portion that circulates the incoming coolant in the vicinity of the through-hole; and

a linear guiding plate that directs the coolant from an outer peripheral side of the first casing to the through-hole located on an inner side of the first casing.

4. The heatsink apparatus according to claim 3, wherein a plurality of heat-dissipating fins are provided in the heat transfer chamber on a surface opposite to the contact surface, protruding from the first casing toward the partition wall member.

5. The heatsink apparatus according to claim 1, wherein the partition wall member is slanted so that a distance between the first casing and the partition wall member in the heat transfer chamber is shorter in a central portion of the heat transfer chamber.

6. A heatsink apparatus having a radiator and a centrifugal pump in a closed circulation channel for circulating a coolant, the centrifugal pump contacting a heat-generating component and releasing heat from the heat-generating component through heat exchange of the coolant therein-side, the radiator dissipating the heat, the centrifugal pump comprising:

a first casing provided with a contact surface that contacts the heat-generating component;

a second casing fitted to the first casing so as to form a space wherein the coolant flows;

a partition wall member provided between the first and second casings so as to form a heat transfer chamber

between the partition wall member and the first casing and to form a pump chamber that houses an impeller between partition wall member and the second casing;

a coolant inlet connected to the heat transfer chamber;

a coolant outlet connected to the pump chamber;

through-holes formed in the partition wall member so as to connect the heat transfer chamber and the pump chamber; and

a pair of guiding plates provided in the heat transfer chamber so as to direct the coolant from the inlet to a central portion of the heat transfer chamber.

7. The heatsink apparatus according to claim 6, wherein the through-holes in the partition wall member are disposed outside the pair of guiding plates.

8. The heatsink apparatus according to claim 6, wherein the guiding plates extend from the inlet of the heat transfer chamber beyond the center of the heat transfer chamber.

9. The heatsink apparatus according to claim 6, wherein a flow separation wall is provided in the heat transfer chamber so as to separate the coolant passing through the guiding plates into two directions in the heat transfer chamber.

10. The heatsink apparatus according to claim 6, wherein the through holes in the partition wall member are disposed in two locations outside the pair of guiding plates.

11. The heatsink apparatus according to claim 6, wherein a plurality of heat-dissipating fins are provided in the heat transfer chamber on a surface opposite to the contact surface, protruding from the first casing toward the partition wall member.

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