HEAT PIPE, COOLING UNIT HAVING THE HEAT PIPE, AND ELECTRONIC APPARATUS HAVING THE COOLING UNIT

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ABSTRACT

According to one embodiment of the invention, a heat pipe features a pipe-shaped container in which an operating fluid is sealed, and a wick provided inside the container. The container has a flat heat-receiving end portion, a heat-radiating end portion being flattened in a direction different from that of the heat-receiving end portion, and a middle portion connecting the heat-receiving end portion and the heat-radiating end portion. The middle portion has a circular cross section.
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CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from prior Japanese Patent Application No. 2003-307423, filed Aug. 29, 2003, the entire contents of which are incorporated herein by reference.

BACKGROUND

1. Field

This invention relates to a heat pipe used for conveying heat of electronic components to a heat sink, and a cooling unit using the heat pipe. Further, this invention relates to an electronic apparatus, such as a portable computer, containing heat-generating electronic components inside its housing. In particular, this invention relates to a structure of conveying heat of electronic components to a heat-radiating portion via the heat pipe.

2. Description of the Related Art

The amount of heat generated by CPUs used in notebook portable computers has increased in response to an increase in their processing speed and functions. As a result, CPUs are now more susceptible in exceeding their thermal threshold, which causes a decrease in operation efficiency or causes inoperability.

Therefore, conventional art provides various heat radiating measures to discharge heat of CPUs to the outside. Heat pipes and heat sinks are known as typical means for cooling CPUs. Jpn. Pat. Appln. KOKAI Pub. No. 2001-251079 discloses an example of a cooling unit having a heat pipe. The heat pipe used in the cooling unit has a pipe-shaped metal container. A wick is housed inside the container, which is sealed to further house operating fluid such as water. The container has a heat receiving end portion and a heat radiating end portion located opposite to the heat receiving end portion. The heat receiving end portion is thermally connected to the CPU with a heat receiving plate interposed therebetween. The heat radiating end portion is thermally connected to a heat sink.

According to the conventional structure, the heat receiving end portion of the container receives heat of the CPU. Thereby, the operating fluid in the heat receiving end portion is heated and vaporized. This vapor flows from the heat receiving end portion to the heat radiating end portion through a vapor channel inside the container. The vapor guided into the heat-radiating end portion condensed therein. Heat radiated by the condensation is diffused by heat conduction from the heat radiating end portion to the heat sink, and radiated from the surface of the heat sink.

The operating fluid liquefied in the heat radiating end portion is conveyed through the wick by capillary action and returns to the heat receiving end portion. The operating fluid returned to the heat receiving end portion receives heat of the CPU again. Heat of the CPU is transferred to the heat sink by the repeated evaporation and condensation of the operating fluid.

In the above conventional cooling unit, the container is flattened through the whole length, to reduce the setting space of the heat pipe. Further, heat is transferred by a heat pipe bent by about ninety degrees (90°) in the horizontal direction, the flattened container is twisted in the third dimension between the heat receiving end portion and the heat radiating end portion, and folded by 180°.

However, if the flattened container is twisted and folded, the heat receiving end portion and the heat radiating end portion are located on almost the same plane. As a result, the heat receiving end portion and the heat radiating end portion are flat in the same direction. Therefore, when a heat sink is thermally connected to the heat radiating end portion of the container, the shape and the orientation of the heat sink may be restricted.

In addition, when the flattened container is twisted and folded, it is inevitable that the wick located inside the container is deformed or crushed as well. This interferes with return of the operating fluid liquefied in the heat radiating end portion to the heat receiving end portion, and thus is an obstacle to efficient heat convey.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

FIG. 1 is a perspective view of an exemplary portable computer according to a first embodiment of the invention.

FIG. 2 is a perspective view of the portable computer of the first embodiment of the invention, illustrating a state where a cooling unit is contained in a housing thereof.

FIG. 3 is a perspective view of an exemplary cooling unit according to the first embodiment of the present invention.

FIG. 4 is a cross-sectional view of an exemplary heat pipe according to the first embodiment of the present invention, illustrating a cross section of a heat-receiving end portion of a container.

FIG. 5 is a cross-sectional view of the exemplary heat pipe according to the first embodiment of the present invention, illustrating a cross section of a heat-radiating end portion of the container.

FIG. 6 is a cross-sectional view of the heat pipe according to the first embodiment of the present invention, illustrating a cross section of a middle portion of the container.

FIG. 7 is a perspective view of a cooling unit according to a second embodiment of the invention.

FIG. 8 is a perspective view of a cooling unit according to a third embodiment of the invention.

FIG. 9 is a perspective view of a cooling unit according to a fourth embodiment of the invention.
FIG. 10 is a perspective view of a cooling unit according to a fifth embodiment of the invention.

FIG. 11 is a perspective view of a cooling unit according to a sixth embodiment of the invention.

FIG. 12 is a perspective view of a portable computer according to a seventh embodiment of the present invention, illustrating a state where a cooling unit is contained in a housing thereof.

FIG. 13A is a plan view of a heat pipe according to the seventh embodiment of the invention.

FIG. 13B is a side view of the heat pipe according to the seventh embodiment of the present invention.

FIG. 14A is a plan view of a heat pipe according to an eighth embodiment of the invention.

FIG. 14B is a side view of the heat pipe according to the eighth embodiment of the invention.

DETAILED DESCRIPTION

A first embodiment of the present invention will now be described based on FIGS. 1 to 6.

FIG. 1 illustrates a portable computer 1 being an example of an electronic apparatus of the present invention. The portable computer 1 comprises a computer main body 2 and a display unit 3. The computer main body 2 has a flat box-shaped housing 4. The housing 4 comprises a bottom wall 4a, an upper wall 4b, right and left side walls 4c, a front wall 4d, and a rear wall (not shown). The upper wall 4b supports a keyboard 5.

The display unit 3 comprises a flat box-shaped display housing 6 and a liquid crystal display panel 7. The display housing 6 is supported on the rear end portion of the housing 4 with hinges (not shown). The liquid crystal display panel 7 is contained in the display housing 6. The liquid crystal display panel 7 has a screen 7a, which displays images. The screen 7a is exposed to the outside of the display unit 3 through an opening 8 formed in the front surface of the display housing 6.

As shown in FIG. 2, the housing 4 contains a printed wiring board 10 and a cooling unit 11. An electronic component 12 as a heat generating component is mounted on an upper surface of the printed wiring board 10. The electronic component 12 is, for example, a CPU serving as the nerve center of the portable computer 1. The electronic component 12 produces a very large amount of heat during operation, due to an increase in the processing speed and functions. The electronic component 12 requires cooling to maintain its stable operation.

The cooling unit 11 is provided to cool the electronic component 12. The cooling unit 11 comprises a heat-receiving portion 13, a cooling fan 14 serving as a heat-radiating portion, and a heat pipe 15.

The heat-receiving portion 13 has a plate shape larger than the electronic component 12, and is formed of a metal material having excellent thermal conductivity, such as aluminum alloy. The heat-receiving portion 13 is fixed on the printed wiring board 10 so as to cover the electronic component 12. A lower surface of the heat-receiving portion 13 is thermally connected to the electronic component 12.

The heat-receiving portion 13 has a fan supporting portion 16. The fan supporting portion 16 projects in a direction away from the electronic component 12 and forms one unitary piece with the heat-receiving portion 13.

The cooling fan 14 comprises a fan casing 18 and an impeller 19. The fan casing 18 is formed of a metal material having excellent thermal conductivity, such as aluminum alloy. The fan casing 18 has an upper wall 20 and a peripheral wall 21. The upper wall 20 is opposed to the fan supporting portion 16. The peripheral wall 21 extends downward from a peripheral edge of the upper wall 20. A lower end portion of the peripheral wall 21 is fixed on the upper surface of the fan supporting portion 16 with screws.

In the first embodiment, the heat-receiving portion 13 and the fan casing 18 are connected via the fan supporting portion 16. Therefore, a portion of the heat provided by the electronic component 12 is conveyed from the heat-receiving portion 13 to the fan casing 18 through the fan supporting portion 16. Thus, the fan casing 18 also functions as a heat radiator.

The peripheral wall 21 of the fan casing 18 has a flat connecting surface 21a. The connecting surface 21a stands on the upper surface of the fan supporting portion 16. The connecting surface 21a and the upper surface of the fan supporting portion 16 have such positional relationship that they are substantially perpendicular to each other.

The impeller 19 is supported by the upper wall 20 of the fan casing 18 with a flat motor 22 interposed therebetween. The flat motor 22 rotates the impeller 19 when, for example, the power of the portable computer 1 is turned on or the temperature of the electronic component 12 reaches a predetermined value.

The upper wall 20 of the fan casing 18 has an intake 23a. The fan supporting portion 16 has an intake 23b. The intakes 23a and 23b are opened to a rotation center portion of the impeller 19, and opposed to each other with the impeller 19 interposed therebetween. The peripheral wall 21 of the fan casing 18 has an outlet 24. The outlet 24 is opposed to a circumferential portion of the impeller 19, and communicates with exhaust ports 25 opened at the side wall 4c of the housing 4.

When the impeller 19 is rotated, the air inside the housing 4 is taken into the rotation center portion of the impeller 19 through the intakes 23a and 23b. The air is emitted as cooling air from the circumferential portion of the impeller 19 by centrifugal force. The cooling air cools the fan casing 18 and the fan supporting portion 16, and is discharged from the outlet 24 to the exhaust ports 25.

The heat pipe 15 comprises a substantially straight circuit operating as a container 30. According to this embodiment of the invention, the container 30 is elongated and hollow so as to be pipe-shaped. The container 30 is formed of a metal material having excellent heat conductivity, such as aluminum, stainless steel or copper, and basically has a circular cross section. As shown in FIGS. 4 and 6, a wick 31 comprising a plurality of grooves is formed on an internal surface of the container 30. The wick 31 extends along the axis of the container 30, with the grooves thereof arranged in the circumferential direction of the container 30 at regular intervals. An operating fluid such as ammonia, alcohol, and water, is sealed in the container 30.
As shown in FIG. 3, the container 30 comprises a heat-receiving end portion 32, a heat-radiating end portion 33, and a middle portion 34. The heat-receiving end portion 32, the heat-radiating end portion 33 and the middle portion 34 are arranged in-line in the radial direction of the container 30. The heat-receiving end portion 32 is located at one end of the container 30, and extends over a fixed length in the radial direction of the container 30. The heat-receiving end portion 32 is formed by flattening the one end of the container 30, and thus, has a (flat) cross section elongated in the radial direction as shown in FIG. 4. In other words, the heat-receiving end portion 32 has two flat heat receiving surfaces 32a and 32b, and a pair of edge portions 32c and 32d. The heat receiving surfaces 32a and 32b are arranged in parallel so as to be opposed to each other in the radial direction of the container 30. Each of the edge portions 32c and 32d spreads over the heat receiving surfaces 32a and 32b, and extends in the radial direction of the container 30.

The heat-radiating end portion 33 is located at the other end of the container 30, and extends over a fixed length in the radial direction of the container 30. The heat-radiating end portion 33 is formed by flattening the other end of the container 30, and thus, has a (flat) cross section elongated in the vertical direction as shown in FIG. 5. In other words, the heat-radiating end portion 33 has two flat heat radiating surfaces 33a and 33b, and a pair of edge portions 33c and 33d. The heat radiating surfaces 33a and 33b are arranged in parallel so as to be opposed to each other in the radial direction of the container 30. Each of the edge portions 33c and 33d spreads over the heat radiating surfaces 33a and 33b, and extends in the radial direction of the container 30.

The heat-radiating end portion 33 is flattened in a direction different from a direction in which the heat-receiving end portion 32 is flattened. In the first embodiment, flattened portions of the heat-radiating end portion 33 and those of the heat-receiving end portion 32 are arranged in positions twisted by 90° in the circumferential direction of the container 30. Thereby, the orientation of the heat-receiving surfaces 32a and 32b and the orientation of the heat radiating surfaces 33a and 33b are different from each other by approximately 90°.

The middle portion 34 connects the heat-receiving end portion 32 and the heat-radiating end portion 33, being interposed between them. As shown in FIG. 6, the middle portion 34 has a circular or oval cross section, maintaining the basic cross section shape of the container 30. The term “circular” in the present invention is defined as including shapes of a circle, an ellipse, and an oval.

As shown in FIG. 3, the container 30 has a pair of boundary portions 35 and 36. One boundary portion 35 is located between the heat-receiving end portion 32 and the middle portion 34. The cross section of the boundary portion 35 gradually changes from a flat shape on the side of the heat-receiving end portion 32 to a circular shape on the side of the middle portion 34. The other boundary portion 36 is located between the heat-radiating end portion 33 and the middle portion 34. The cross section of the boundary portion 36 gradually changes from a flat shape on the side of the heat-radiating end portion 33 to a circular shape on the side of the middle portion 34.

The container 30 of the heat pipe 15 extends over the upper surface of the heat-receiving portion 13 and the fan casing 18. The one heat receiving surface 32a of the heat-receiving end portion 32 is thermally connected to the upper surface of the heat-receiving portion 13 by soldering or the like. The heat receiving surface 32a is opposed to the electronic component 12 with the heat-receiving portion 13 interposed therebetween.

The one heat radiating surface 33a of the heat-radiating end portion 33 is thermally connected to the connecting surface 21a of the fan casing 18 by soldering or the like. The connecting surface 21a of the fan casing 18 and the upper surface of the heat receiving surface 13 have such a positional relationship that they are orthogonal to each other. In conformity with this, in the heat pipe 15, the orientations of the heat-receiving end portion 32 and the heat-radiating end portion 33 are shifted by 90° in the circumferential direction of the container 30. Therefore, it is possible to thermally connect the heat-radiating end portion 33 of the heat pipe 15 to the connecting surface 21a of the fan casing 18, in the state where the heat-receiving end portion 32 of the heat pipe 15 is thermally connected to the upper surface of the heat-receiving portion 13.

When the electronic component 12 generates heat, the heat of the electronic component 12 is transmitted to the heat-receiving portion 13. The heat-receiving end portion 32 of the heat pipe 15 receives the heat of the electronic component 12 from the heat-receiving portion 13. Thereby, the operating fluid inside the heat-receiving end portion 32 is heated and vaporized. This vapor flows from the heat-receiving end portion 32 toward the heat-radiating end portion 33 through the middle portion 34. The vapor guided into the heat-radiating end portion 33 is condensed therein. Heat liberated by this condensation is diffused by heat conduction from the heat-radiating end portion 33 to the fan casing 18, and radiated from the surface of the fan casing 18.

The operating fluid liquefied in the heat-radiating end portion 33 is conveyed through the wick 31 by capillary action and returns to the heat-receiving end portion 32. The operating fluid returned to the heat-receiving end portion 32 receives heat of the electronic component 12 again. Heat of the electronic component 12 is conveyed to the fan casing 18 by the repeated evaporation and condensation of the operating fluid.

According to the above structure, the heat-radiating end portion 33 of the heat pipe 15 is flattened in a direction twisted by 90° with respect to the heat-receiving end portion 32 of the heat pipe 15 in the circumferential direction of the container 30. Therefore, it is possible to solder the heat-radiating end portion 33 to the connecting surface 21a of the fan casing 18 standing on the heat-receiving portion 13, in the state where the heat-receiving end portion 32 is soldered to the upper surface of the heat-receiving portion 13.

In other words, supposing that the heat-receiving end portion 32 and the heat-radiating end portion 33 of the heat pipe 15 are flattened in the same direction, in the state where the heat-receiving end portion 32 is soldered to the heat-receiving portion 13, the flat portions of the heat-radiating end portion 33 are perpendicular to the connecting surface 21a of the fan casing 18. Therefore, the flat surface of the heat-radiating end portion 33 cannot be brought into contact with the connecting surface 21a. Consequently, it is required to change the shape of the fan casing 18 or mounting orientation of the cooling fan 14.
On the other hand, according to the above structure, the heat-radiating end portion 33 of the heat pipe 15 can be thermally connected to the fan casing 18, without changing the shape of the fan casing 18 and the mounting orientation of the cooling fan 14. Therefore, the shape of the fan casing 18 is not restricted, and the flexibility in the mounting orientation of the fan casing 18 with respect to the heat-receiving portion 33 is increased.

Further, the middle portion 34 connecting the heat-receiving end portion 32 and the heat-radiating end portion 33 still has a circular cross section. Therefore, the wick 31 on the internal surface of the middle portion 34 is neither deformed nor crushed. Thus, the operating fluid smoothly flows between the heat-receiving end portion 32 and the heat-radiating end portion 33, and heat of the electronic component 12 is efficiently conveyed to the fan casing 18.

In the first embodiment, the heat-receiving end portion 32 and the heat-radiating end portion 33 of the container are soldered to the heat-receiving portion and the fan casing, respectively. However, the present invention is not limited to this structure. For example, a structure may be adopted wherein a fitting groove is formed on each of the heat-receiving portion and the fan casing 18 and the heat-receiving end portion 32 and the heat-radiating end portion 33 of the container are fitted in the respective grooves.

In addition, the wick is not limited to grooves formed on the internal surface of the container. For example, a wick material formed of glass fiber or net-shaped thin line material may be fitted inside the container.

The present invention is not limited to the first embodiment. FIG. 7 discloses a second embodiment of the invention.

The second embodiment is different from the first embodiment mainly in the structure of a cooling unit 41. The cooling unit 41 has a heat-receiving portion 42 and a heat-radiating portion 43. The heat-receiving portion 42 and the heat-receiving portion 43 are separated from each other. The heat-receiving portion 42 has a flat board form with a size corresponding to an electronic component 12, and is formed of a metal material having excellent heat conductivity, such as aluminum alloy. The heat-receiving portion 42 has a flat connecting surface 42a on the side reverse to the side on which the electronic component 12 exists.

The heat-radiating portion 43 comprises a plurality of heat radiating fins 44, and a frame 45 supporting the heat radiating fins 44. The heat radiating fins 44 are arranged in parallel at regular intervals. The cooling air flows between adjacent heat radiating fins 44. The frame 45 has a flat connecting surface 45a. The connecting surface 45a extends in a direction in which the heat radiating fins 44 are arranged. The connecting surface 45a of the frame 45 and the connecting surface 42a of the heat-receiving portion 42 have such positional relationship that they are orthogonal to each other.

The heat-receiving portion 42 and the heat-radiating portion 43 are thermally connected by a heat pipe 15 having the same structure as in the first embodiment. A heat-receiving end portion 32 of the heat pipe 15 is soldered to the connecting surface 42a of the heat-receiving portion 42. A heat-radiating end portion 33 of the heat pipe 15 is soldered to the connecting surface 45a of the frame 45.

According to the above structure, the heat-receiving portion 42 and the heat-radiating portion 43 can be thermally connected by the heat pipe 15, even if the connecting surface 42a of the heat-receiving portion 42 is orthogonal to the connecting surface 45a of the heat-radiating portion 43. Therefore, it is possible to efficiently convey heat of the electronic component 12, which has been transmitted to the heat-receiving portion 42, to the heat-radiating portion 43 by the heat pipe 15.

FIG. 8 discloses a third embodiment of the invention.

The third embodiment is different from the second embodiment in structure of a heat-radiating portion 51. The other parts of the structure of a cooling unit 41 are the same as those in the second embodiment.

As shown in FIG. 8, the heat-radiating portion 51 has a board shape with almost the same size as that of a heat-receiving portion 42, and is formed of a material having excellent heat conductivity, such as aluminum alloy. The heat-receiving portion 51 has a flat connecting surface 51a. The connecting surface 51a of the heat-radiating portion 51 and a connecting surface 42a of the heat-receiving portion 42 have such a positional relationship that they are orthogonal to each other. A heat-receiving end portion 33 of the heat pipe 15 is soldered to the connecting surface 51a of the heat-radiating portion 51.

FIG. 9 discloses a fourth embodiment of the invention.

The fourth embodiment is an extension of the second embodiment. As shown in FIG. 9, a heat pipe 15 has a bent portion 61, which has an arc-shaped bend, in a middle portion 34 of its container 30. For example, the bend is approximately ninety degrees (90°) for this embodiment. By the existence of the bent portion 61, a heat-receiving end portion 32 and a heat-radiating end portion 33 of the heat pipe 15 extend in directions orthogonal to each other. In other words, an axis 0 of the heat-receiving end portion 32 and an axis 0 of the heat-radiating end portion 33 cross at right angles in a position corresponding to the bent portion 61. Therefore, the heat conveying direction of the heat pipe 15 according to the fourth embodiment turns by approximately 90°.

Further, in the fourth embodiment, the heat-receiving end portion 32 and the heat-radiating end portion 33 are shifted from each other by a 45° twist in a circumferential direction of the container 30. Thereby, the orientation of a heat receiving surface 32a of the heat-receiving end portion 32 is different from the orientation of a heat radiating surface 33a of the heat-radiating end portion 33.

A heat-radiating portion 43 of the cooling unit 41 comprises a plurality of heat radiating fins 62 and a frame 63 supporting the heat radiating fins 62. Each heat radiating fin 62 is flat plate shape. The heat radiating fins 62 are arranged in parallel at regular intervals, and stand in a vertical direction. The frame 63 has a connecting surface 63a. The connecting surface 63a extends in a direction in which the heat radiating fins 62 are arranged, and is inclined by about 45° with respect to the standing direction of the heat radiating fins 62. The angle of inclination of the connecting surface 63a corresponds to a twist angle of the heat-radiating end portion 33 with respect to the heat-
receiving end portion 32 of the heat pipe 15. The heat-radiating end portion 33 of the heat pipe 15 is soldered to the connecting surface 63a of the frame 63.

According to the above structure, the container 30 of the heat pipe 15 is bent in the position of the middle portion 34 which keeps a circular cross section. Therefore, it is possible to reduce the radius of the bent portion 61 in comparison with the case of bending a flat container. Therefore, the heat-receiving end portion 32 and the heat-radiating end portion 33 are close to each other. This makes the cooling unit 41 compact, and enables reduction in the space necessary for setting the cooling unit 41.

Besides, the bent portion 61 of the heat pipe 15 is located in the middle portion 34 having a circular cross section. This prevents deformation and crush of the wick 31 on the internal surface of the bent portion 61. It is thus possible to efficiently convey heat from the heat-receiving portion 42 to the heat-radiating portion 43.

FIG. 10 discloses a fifth embodiment of the present invention.

The fifth embodiment is a further extension of the third embodiment. The basic structure of a cooling unit 41 of the fifth embodiment is the same as that in the third embodiment.

As shown in FIG. 10, a heat pipe 15 has a step portion 71 in a middle portion 34 of a container 30. The step portion 71 is bent like a crank to couple the openings of the step portion 71 to corresponding laterally offset boundary portions 35 and 36. The presence of the step portion 71 generates difference in level between a heat-receiving end portion 32 and a heat-radiating end portion 33, and the heat-receiving end portion 32 and the heat-radiating end portion 33 are displaced from each other in the radial direction of the container 30.

According to the above structure, the container 30 of the heat pipe 15 is bent like a crank in the position of the middle portion 34 which keeps a circular cross section. It prevents the wick 31 on the internal surface of the container 30 from being deformed and crushed, in comparison with the case of bending a flat container. It is thus possible to efficiently convey heat from the heat-receiving portion 42 to the heat-radiating portion 43.

FIG. 11 discloses a sixth embodiment of the present invention.

The sixth embodiment is an extension of the fourth embodiment. The basic structure of a cooling unit 41 of the sixth embodiment is the same as that in the fourth embodiment.

As shown in FIG. 11, a heat pipe 15 has a step portion 81 in a middle portion 34 of a container 30. The step portion 81 is bent like a crank, and located next to a bent portion 61. The presence of the step portion 81 generates difference in level between a heat-receiving end portion 32 and a heat-radiating end portion 33, and the heat-receiving end portion 32 and the heat-radiating end portion 33 are displaced from each other in the radial direction of the container 30. Therefore, the heat pipe 15 of this embodiment is bent in three dimensions.

FIGS. 12, 13A and 13B disclose a seventh embodiment of the present invention.

The seventh embodiment is different from the first embodiment in the form of a heat pipe 15. The other parts of the basic structure of a cooling unit 11 in the seventh embodiment are the same as those in the first embodiment.

The heat pipe 15 has a middle portion 91 connecting a heat-receiving end portion 32 and a heat-radiating end portion 33. The heat-receiving end portion 32 and the heat-radiating end portion 33 have a positional relationship in which they are displaced by 90° in the circumferential direction of a container 30. The orientation of heat receiving surfaces 32a and 32b is different by 90° from the orientation of heat radiating surfaces 33a and 33b. This is the same as in the first embodiment.

As shown in FIGS. 13A and 13B, the middle portion 91 of the heat pipe 15 has an angular pipe shape. The middle portion 91 has a pair of first surfaces 92a and 92b, and a pair of second surfaces 93a and 93b. One first surface 92a connects one heat receiving surface 32a of the heat-receiving end portion 32 and one edge portion 33c of the heat-radiating end portion 33. Therefore, the edge portion 33c of the heat-radiating end portion 33 is connected with the heat receiving surface 32a with the first surface 92a interposed therebetween.

The other first surface 92b connects the other heat receiving surface 32b of the heat-receiving end portion 32 and the other edge portion 33d of the heat-radiating end portion 33. The first surface 92b is located on the reverse side of the first surface 92a. The two first surfaces 92a and 92b are gradually inclined so as to move away from each other, in the direction from the heat-receiving end portion 32 to the heat-radiating end portion 33. Therefore, the first surfaces 92a and 92b are not parallel with each other, and connect to the heat receiving surfaces 32a and 32b, respectively, of the heat-receiving end portion 32.

The second surface 93a connects one heat radiating surface 33a of the heat-radiating end portion 33 and one edge portion 32c of the heat-receiving end portion 32. In other words, the edge portion 32c of the heat-receiving end portion 32 is connected with the heat radiating surface 33a with the second surface 93a interposed therebetween.

The other second surface 93b connects the other heat radiating surface 33b of the heat-receiving end portion 33 and the other edge portion 32d of the heat-receiving end portion 32. Therefore, the edge portion 32d of the heat-receiving end portion 32 is connected with the heat radiating surface 33b with the second surface 93b interposed therebetween.

The one second surface 93a is located on the reverse side of the other second surface 93b. The two second surfaces 93a and 93b are gradually declined so as to move closer to each other, in the direction from the heat-receiving end portion 32 to the heat-radiating end portion 33. Therefore, the second surfaces 93a and 93b are not parallel with each other, and connect with the heat radiating surfaces 33a and 33b, respectively, of the heat-radiating end portion 33.

According to the above structure, the middle portion 91 connecting the heat-receiving end portion 32 and the heat-radiating end portion 33 has an angular pipe shape having the first surfaces 92a and 92b not being parallel and the second surfaces 93a and 93b not being parallel. This prevents deformation and crush of wick 31 on the internal
surface of the middle portion 91. It is thus possible to efficiently convey heat from a heat-receiving portion 42 to a heat-radiating portion 43, although the orientations of the heat-receiving end portion 32 and the heat-radiating end portion 33 are displaced from each other in the circumferential direction of the container 30.

[0087] FIGS. 14A and 14B disclose an eighth embodiment of the present invention.

[0088] The eighth embodiment is different from the seventh embodiment in the form of a middle portion 91 of a heat pipe 15. The other parts of the structure of the heat pipe 15 in the eighth embodiment is the same as those in the seventh embodiment.

[0089] As shown in FIG. 14B, one first surface 92a of the middle portion 91 is located on the same plane as one heat receiving surface 32a of a heat-receiving end portion 32 and one edge portion 33c of a heat-radiating end portion 33. The other first surface 92b is gradually inclined to move away from the first surface 92a, in the direction from the heat-receiving end portion 32 to the heat-radiating end portion 33.

[0090] One second surface 93a of the middle portion 91 is inclined to become gradually close to the other second surface 93b, in the direction from the heat-receiving end portion 32 to the heat-readiing end portion 33. The other second surface 93b of the middle portion 91 is located on the same plane as the other heat radiating surface 33b of the heat-radiating end portion 33 and the other edge portion 32d of the heat-receiving end portion 32.

[0091] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

1. A heat pipe comprising:
   a sealed container including an operating fluid, the container comprises a heat-receiving end portion flattened in a first direction, a heat-radiating end portion flattened in a second direction differing from the first direction, and a middle portion having a non-flattened cross section and connecting the heat-receiving end portion and the heat-radiating end portion; and
   a wick provided inside the container.

2. A heat pipe according to claim 1, wherein the middle portion of the container has a circular cross section.

3. A heat pipe according to claim 1, wherein the middle portion of the container includes an arc-shaped bent portion.

4. A heat pipe according to claim 1, wherein the middle portion of the container includes a first opening for coupling to the heat-receiving end portion and a second opening for coupling to the heat-radiating end portion, the first opening being laterally offset from the second opening.

5. A heat pipe according to claim 1, wherein the middle portion of the container being a conduit including an arc-shaped portion coupled to a crank-shaped portion having a first opening laterally offset from a second opening.

6. A heat pipe according to claim 1, wherein the heat-receiving end portion of the container has two parallel heat receiving surfaces, the heat-radiating end portion of the container has two parallel heat radiating surfaces, and orientation of the heat-receiving surfaces is different from orientation of the heat-radiating surfaces in a circumferential direction of the container.

7. A heat pipe according to claim 1, wherein the wick is situated inside the middle portion of the container.

8. A heat pipe comprising:
   a sealed container housing an operating fluid, the container comprises a heat-receiving end portion flattened in a first direction, a heat-radiating end portion flattened in a second direction different from the first direction, and an arc-shaped middle portion having a circular cross section coupled between the heat-receiving end portion and the heat-radiating end portion; and
   a wick provided inside the container.

9. A heat pipe according to claim 8, wherein the heat-receiving end portion and the heat-radiating end portion extends in directions different from each other, with the middle portion interposed therebetween.

10. A heat pipe according to claim 8, wherein the wick is situated inside the middle portion of the container.

11. A heat pipe comprising:
   a sealed container including an operating fluid, the container comprises a heat-receiving end portion having a cross section elongated in a first direction, a heat-radiating end portion having a cross section elongated in a second direction different than the first direction, and a middle portion coupling the heat-receiving end portion and the heat-radiating end portion, the heat-receiving end portion, the heat-radiating end portion and the middle portion are arranged in-line, each of the heat-receiving end portion and the heat-radiating end portion has two surfaces substantially in parallel, and the middle portion includes a first pair of non-parallel surfaces coupled to the two respective surfaces of the heat-receiving end portion and a second pair of non-parallel surfaces coupled to the two respective surfaces of the heat-radiating end portion; and
   a wick provided inside the container.

12. A heat pipe according to claim 11, wherein each of the heat-receiving end portion and the heat-radiating end portion has a pair of edge portions extending in an axial direction of the container, the edge portions of the heat-receiving end portion are coupled to the two respective surfaces of the heat-radiating end portion with the second pair of non-parallel surfaces of the middle portion interposed therebetween, and the edge portions of the heat-radiating end portion are coupled to the two respective surfaces of the heat-receiving end portion with the first pair of non-parallel surfaces of the middle portion interposed therebetween.

13. A cooling unit comprising:
   a heat-receiving portion thermally connected to a heat generating component;
   a heat-radiating portion radiating heat from the heat generating component; and
   a heat pipe which conveys heat by the heat generating component from the heat-receiving portion to the heat-radiating portion, the heat pipe comprising a pipe-shaped container sealed to house a heat-conveying operating fluid and a wick, the container comprises a
heat-receiving end portion having a cross section elongated in a first direction, a heat-radiating end portion having a cross section elongated in a second direction differing from the first direction, and a middle portion connecting the heat-receiving end portion and the heat-radiating end portion, the middle portion having a circular cross section.

14. A cooling unit according to claim 13, wherein the heat-receiving portion has a supporting portion which supports the heat-radiating portion.

15. A cooling unit according to claim 13, wherein the heat-radiating portion comprises a fan casing thermally connected to the heat-radiating end portion of the heat pipe and an impeller contained in the fan casing.

16. A cooling unit according to claim 15, wherein the fan casing includes a peripheral wall extending in a direction perpendicular to the heat-receiving portion and thermally connected to the heat-radiating end portion of the heat pipe.

17. A cooling unit according to claim 13, wherein the heat-receiving end portion of the container of the heat pipe has two heat receiving surfaces substantially in parallel with each other, the heat-radiating end portion has two heat radiating surfaces substantially in parallel with each other, and orientation of the heat receiving surfaces is different from orientation of the heat radiating surfaces in a circumferential direction of the container.

18. A cooling unit according to claim 13, wherein the middle portion of the container includes an arc-shaped portion.

19. A cooling unit according to claim 13, wherein the middle portion of the container includes a first portion for coupling to the heat-receiving end portion and a second portion for coupling to the heat-radiating end portion, the first portion being laterally offset from the second portion.

20. A cooling unit according to claim 13, wherein the middle portion of the container being a conduit including an arc-shaped first portion coupled to a second portion having a first opening laterally offset from a second opening.

21. A cooling unit according to claim 13, wherein the heat-radiating portion includes a plurality of heat radiating fins arranged with regular intervals and thermally connected to the heat-radiating end portion of the heat pipe.

22. A cooling unit comprising:

a heat-receiving portion adapted to be thermally connected to a heat generating component;

a heat-radiating portion adapted to radiate heat from the heat generating component; and

a heat pipe for conveying the heat of the heat generating component from the heat-receiving portion to the heat-radiating portion, the heat pipe comprising a container formed as a sealed conduit including a heat-conveying operating fluid and a wick inside the container, the container comprises a flat heat-receiving end portion having a cross section elongated in a first direction, a flat heat-radiating end portion having a cross section elongated in a second direction different than the first direction, and a middle portion connecting the heat-receiving end portion and the heat-radiating end portion having a circular cross section.

23. A cooling unit according to claim 22, wherein the heat-receiving end portion and the heat-radiating end portion extend in directions different from each other, with the middle portion interposed therebetween.

24. A cooling unit comprising:

a heat-receiving portion thermally connected to a heat generating component;

a heat-radiating portion adapted to radiate heat from the heat generating component; and

a heat pipe which conveys heat from the heat-receiving portion to the heat-radiating portion, the heat pipe comprising a sealed, pipe-shaped container including a heat-conveying operating fluid and a wick housed inside the container, the container comprises a flat heat-receiving end portion having a cross section elongated in a first direction, a flat heat-radiating end portion having a cross section elongated in a second direction differing from the first direction, and a middle portion connecting the heat-receiving end portion and the heat-radiating end portion, the heat-receiving end portion, the heat-radiating end portion and the middle portion are arranged in-line, each of the heat-receiving end portion and the heat-radiating end portion has two surfaces substantially in parallel, and the middle portion has a first pair of non-parallel surfaces coupled to the two respective surfaces of the heat-receiving end portion, and a second pair of non-parallel surfaces coupled to the two respective surfaces of the heat-radiating end portion.

25. A cooling unit according to claim 24, wherein each of the heat-receiving end portion and the heat-radiating end portion includes a pair of edge portions extending in an axial direction of the container, the edge portions of the heat-receiving end portion are coupled to the two respective surfaces of the heat-radiating end portion with the second pair of non-parallel surfaces of the middle portion interposed therebetween, and the edge portions of the heat-radiating end portion are coupled to the two respective surfaces of the heat-receiving end portion with the respective first pair of non-parallel surfaces of the middle portion interposed therebetween.

26. An electronic apparatus comprising:

a housing having a heat generating component;

a heat-receiving portion contained in the housing and thermally connected to the heat generating component; and

a heat pipe which conveys the heat from the heat-receiving portion to the heat-radiating portion, the heat pipe comprising a pipe-shaped container in which a heat-conveying operating fluid is sealed, and a wick provided inside the container, the container comprises a flat heat-receiving end portion, a heat-radiating end portion being flattened in a direction different from that of the heat-receiving end portion, and a middle portion connecting the heat-receiving end portion and the heat-radiating end portion and having a circular cross section.

27. An electronic apparatus according to claim 26, wherein the middle portion of the container of the heat pipe is bent into an arc-shaped portion.

28. An electronic apparatus according to claim 26, wherein the housing has an exhaust port, the heat-radiating
portion includes a fan casing thermally connected to the heat-radiating end portion of the container, the fan casing includes an outlet and contained in the housing with the outlet opposed to the exhaust port.

29. An electronic apparatus comprising:

a housing including a heat generating component and a heat-receiving portion thermally connected to the heat generating component;

a heat-radiating portion to radiate heat of the heat generating component; and

a heat pipe which conveys the heat from the heat-receiving portion to the heat-radiating portion, the heat pipe comprises a pipe-shaped container in which a heat-conveying operating fluid is sealed, and a wick provided inside the container, the container having a flat heat-receiving end portion, a heat-radiating end portion being flattened in a direction different from that of the heat-receiving end portion, and a middle portion connecting the heat-receiving end portion and the heat-radiating end portion, the heat-receiving end portion, the heat-radiating end portion and the middle portion are arranged in-line, each of the heat-receiving end portion and the heat-radiating end portion has two surfaces substantially in parallel, and the middle portion has two first non-parallel surfaces connecting with the two respective surfaces of the heat-receiving end portion, and two second non-parallel surfaces connecting with the two respective surfaces of the heat-radiating end portion.