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(54) **TURBULATOR FOR LIQUID COOLING SYSTEM FOR COMPUTERS**

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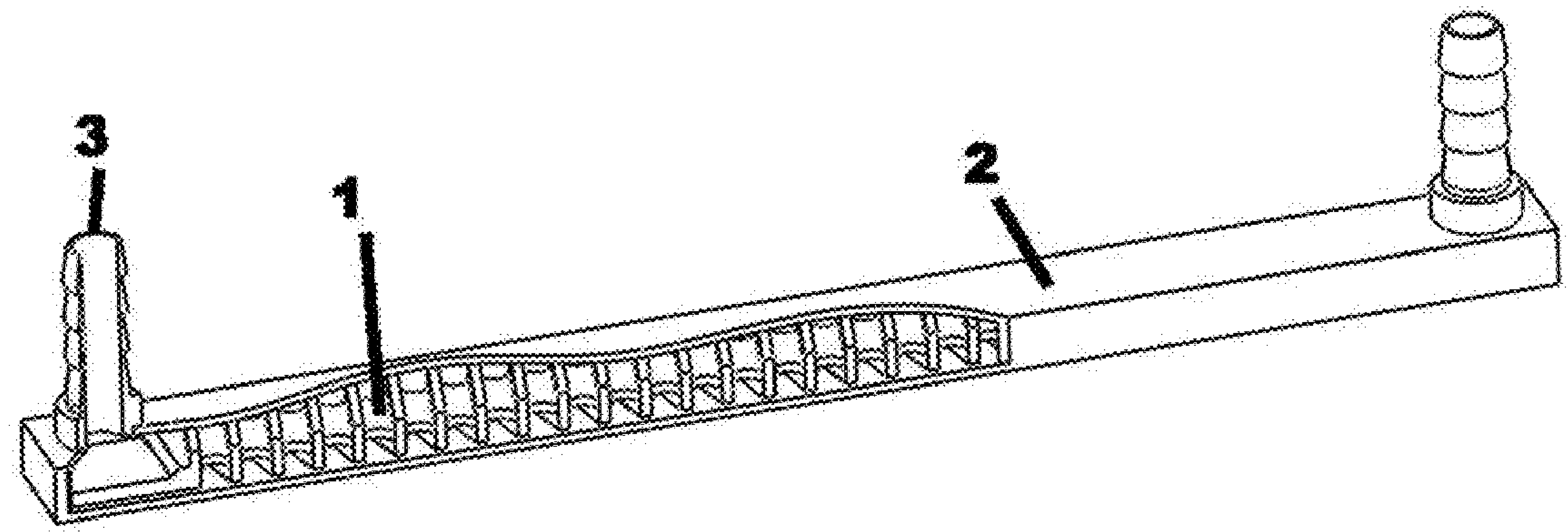
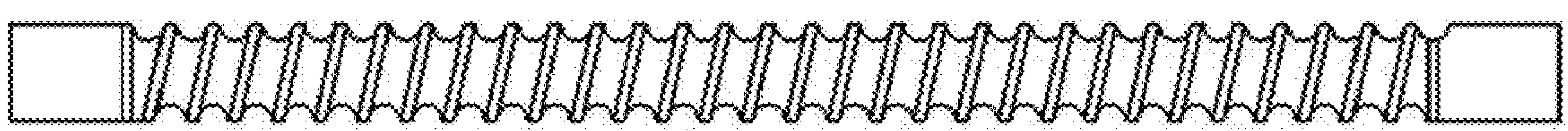
(57) **ABSTRACT**

A turbulator for use in cooling computer systems is disclosed. The turbulator is disposed in a heat exchanger tube and is configured to force the fluid in a path with length more than twice the largest dimension of said heat exchanger tube. By increasing the path and thus the surface area of the heat exchanger in contact with the fluid, and by causing the fluid to swirl in the heat exchanger tube, the turbulator achieves a higher heat dissipation efficiency for the computer cooling system.





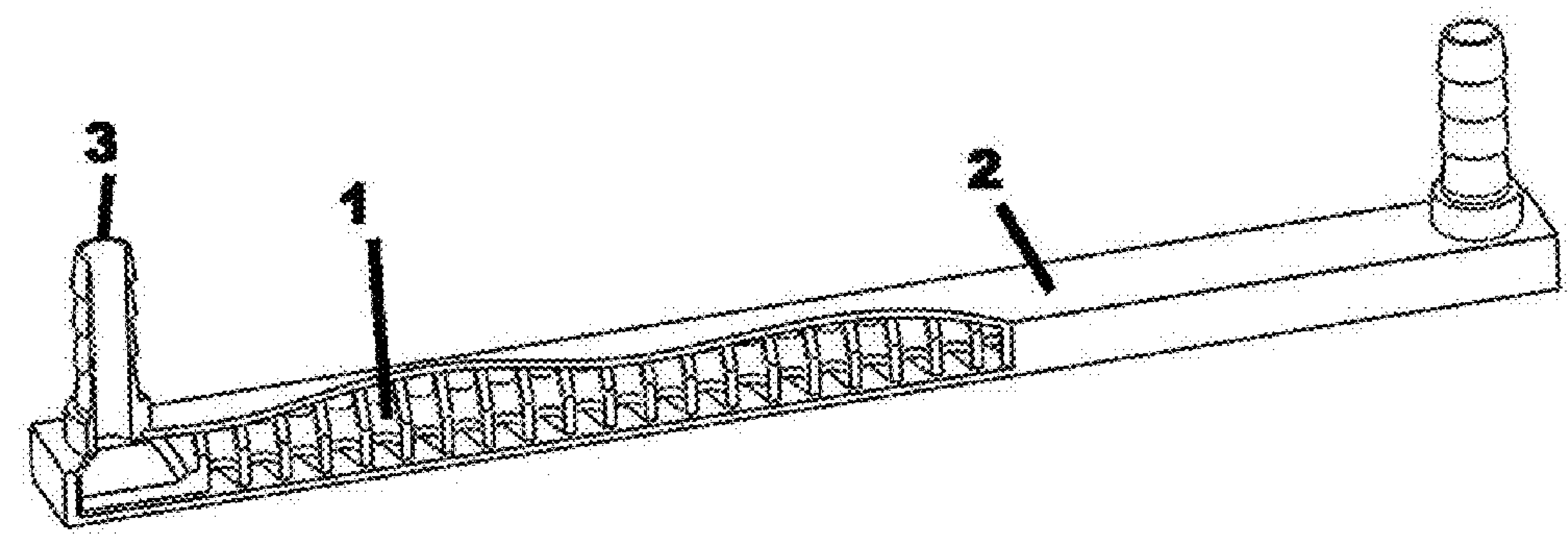


Fig 1A

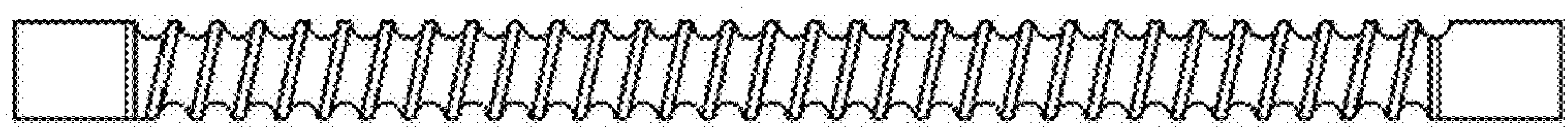


Fig 1B

Fig 1C

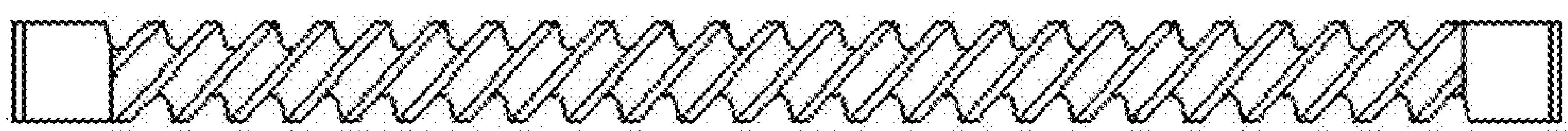


Fig 2

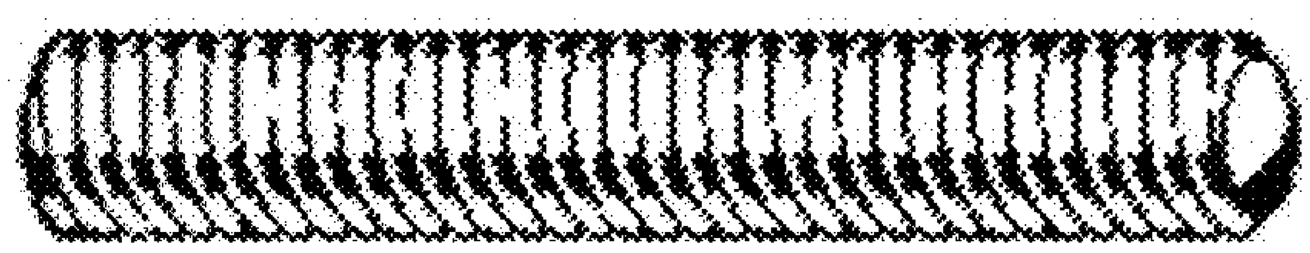


Fig 3

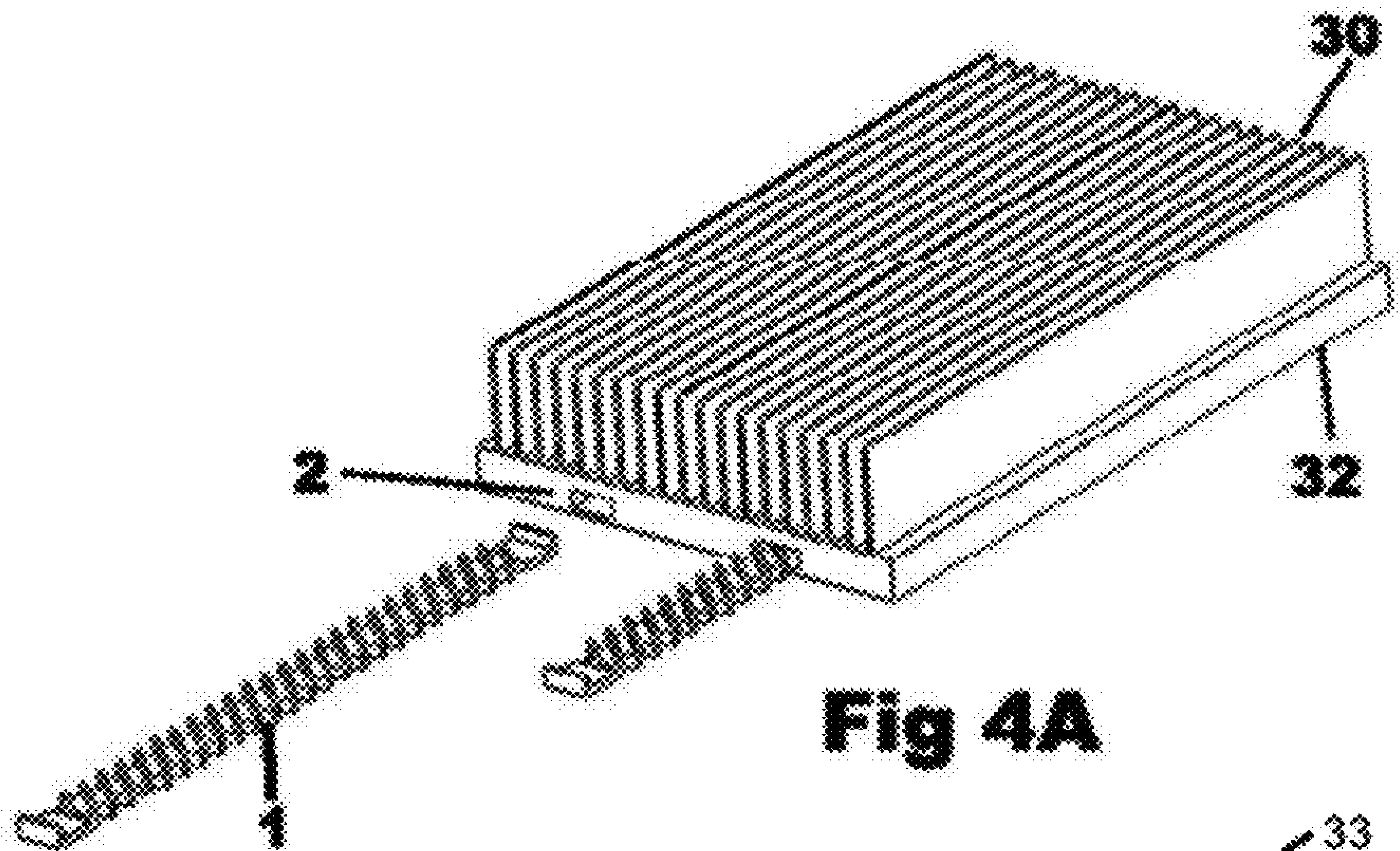


Fig 4A

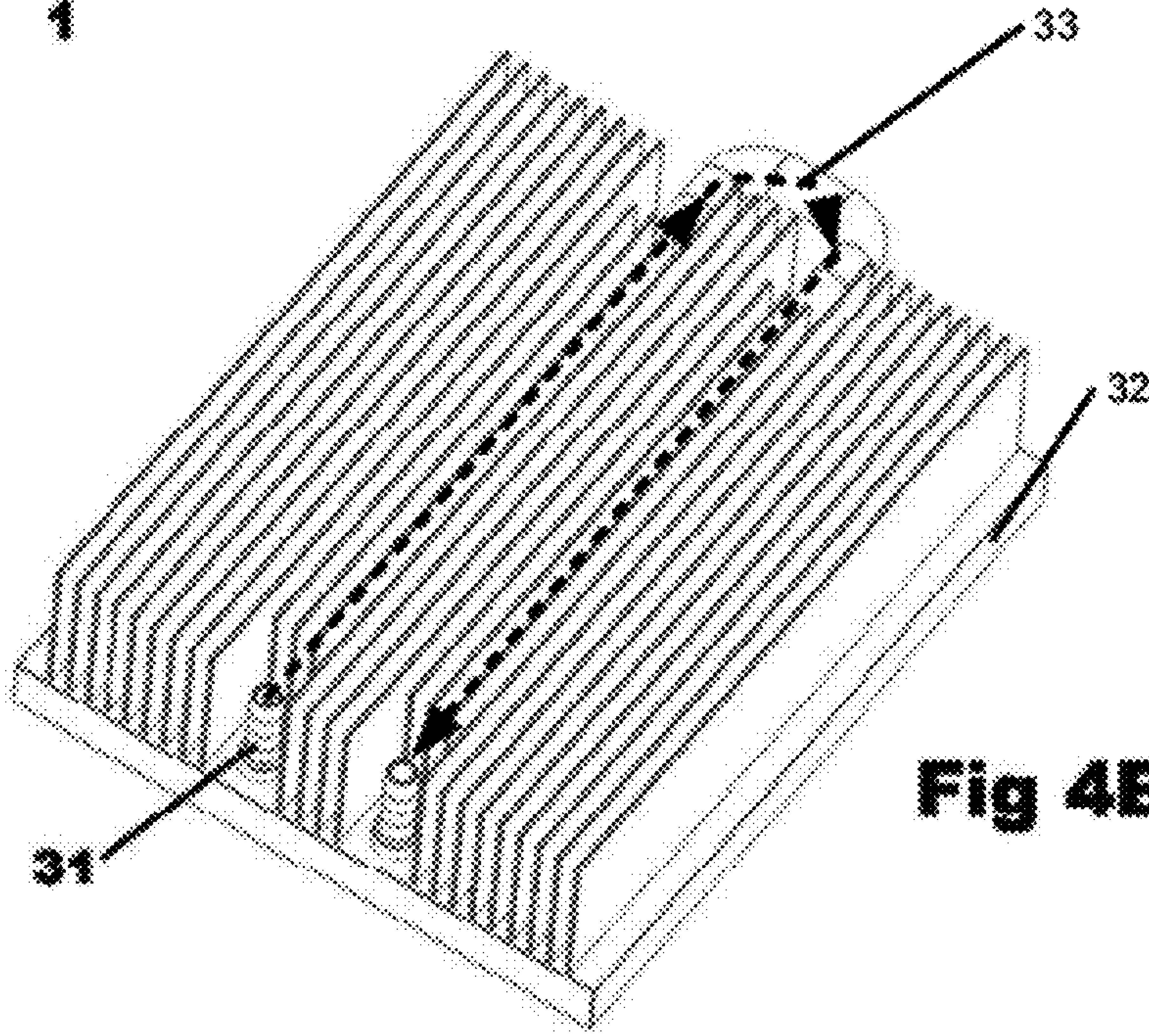


Fig 4B

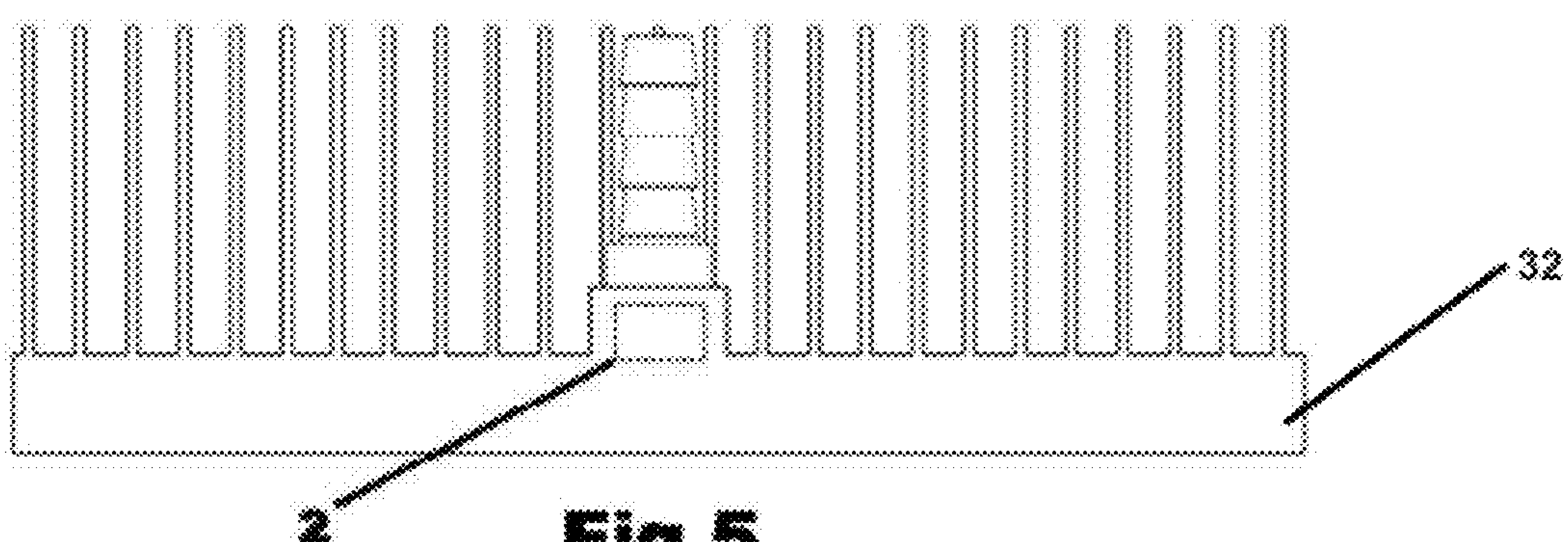


Fig 5

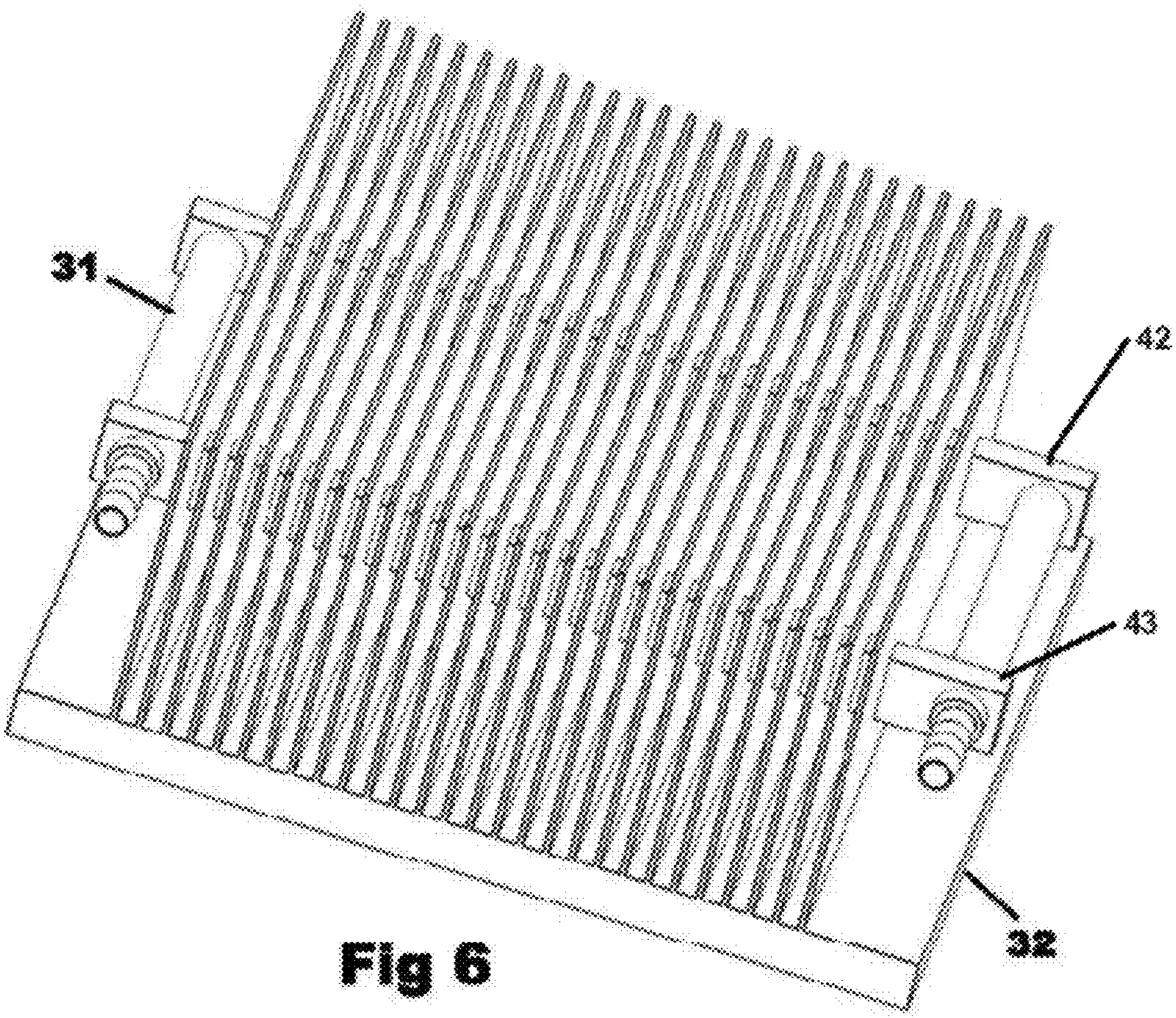

31
42
43
32

Fig 6

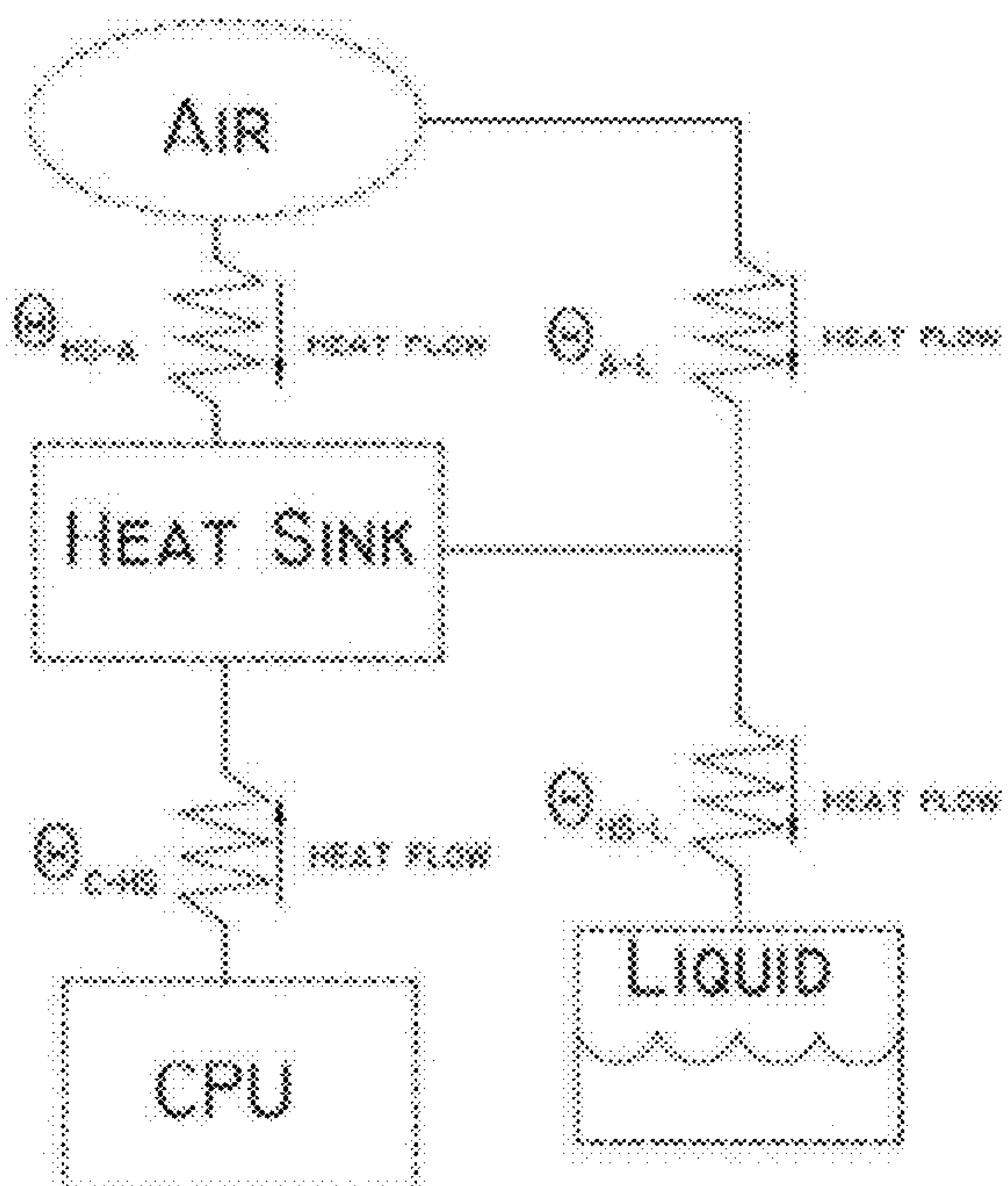

AIR
HEAT FLOW
HEAT FLOW
HEAT SINK
HEAT FLOW
HEAT FLOW
LIQUID
CPU

Fig 7

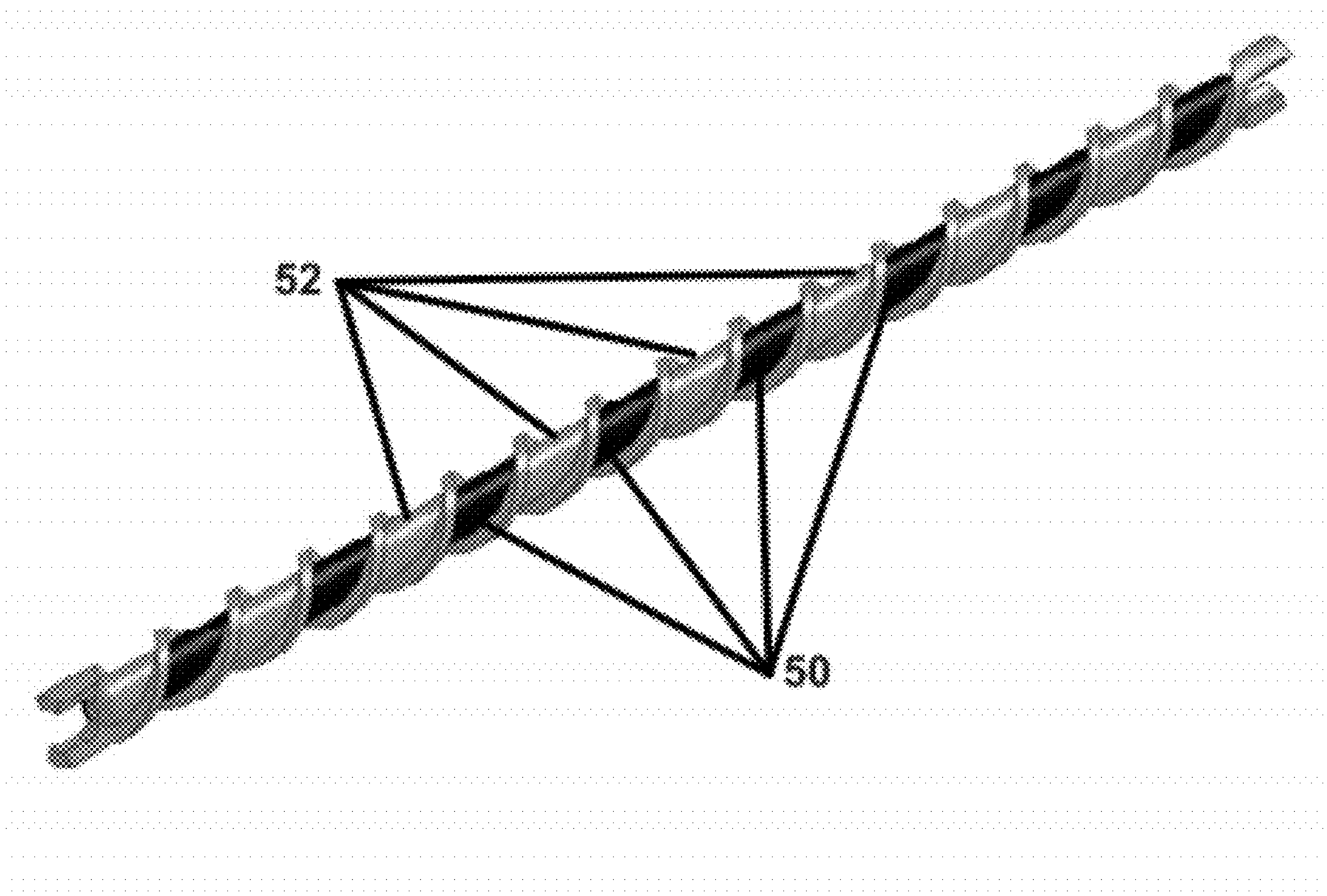


FIG. 8

TURBULATOR FOR LIQUID COOLING SYSTEM FOR COMPUTERS

BACKGROUND OF THE DISCLOSURE

[0001] Arrays of electronic computers, such as are found in data centers, generate a great deal of heat. Liquid cooling is recognized as an excellent way to cool computer CPUs due to the high concentration of power, but the rest of the electronics puts out heat at a lower level and at a lower intensity, so air-cooling is appropriate for much of the associated hardware. Current systems may use liquid cooling the move the heat from the CPU to a radiator mounted close to the CPU, or they may use an air to liquid heat exchanger to remove heat from the computer enclosure and heat up liquid in the heat exchangers. These systems suffer from the high thermal resistance and bulkiness of liquid to air heat exchangers. Other systems use a chilled water loop to cool the computer, but these systems require complex and expensive connectors and plumbing to connect the server to the building water supply while insuring that no leaks occur. Furthermore, chillers require a large amount of power. Since the air-cooling system is already required, air-cooling should be used as a backup for the water-cooling for the CPU and other heat producing components. For operation in a data center, servers, particularly blade servers, need to be compact. Therefore, an ideal CPU heat exchanger would be compact, would use water-cooling as the primary means of cooling with air-cooling as a backup system. Furthermore, the expense and difficulty of servicing the plumbing system would be reduced if the system ran at less than atmospheric pressure, so that leaks are of air into the cooling system, instead of liquid into the data center. Therefore an ideal CPU cooling system would use liquid as the primary means of cooling, with air backup and both the air and liquid heat exchangers would be coupled to the CPU. Furthermore, if the liquid cooling system is operational, the air cooled portion of the heat exchanger may be used to remove heat from the air inside the server enclosure, thereby using the CPU heat exchanger as a way to remove heat from the server and the data center environment.

[0002] Therefore it is an object of the present invention to provide an efficient and compact liquid heat exchanger for a CPU under negative pressure, with a minimal chance of leakage, and with an air-cooling backup system. It is also an object of the present invention to provide a cooling solution which integrates with an air-cooled heat sink for backup and utilizes only the minimum amount of water to provide adequate cooling for each heat-generating element. Furthermore, it is an object of the present invention to provide a way to cool the CPU, the server and the data center with liquid in an optimal manner, cooling the CPU to reduce the leakage current, removing heat for the data center in general by means of the air cooled portion of the CPU heat exchanger, and utilizing an outdoor evaporative cooling system so as to eliminate the need for a chiller in the liquid cooling system.

SUMMARY OF THE DISCLOSURE

[0003] A liquid cooled heat exchanger utilizes a turbulator in a tube to enhance the heat transfer from the liquid to a heat-generating component. It does this by reducing the cross sectional area and increasing the length of the flow path through said tube. This may be done, for example, by placing a threaded rod in a tube with a small diametrical clearance. The heat exchanger is designed to take up the minimum amount of space, while providing maximum heat transfer, and requiring only a modest pressure drop. The turbulator itself displaces much of the volume inside the heat exchanger, reducing the amount of coolant inside the electronics environment. In addition the system may include an air-cooled heat exchanger attached to each CPU to remove the heat in the event that the liquid cooling system is not operating.

[0004] The water-cooled heat exchanger may be mounted to the CPU and comprises a passage with a turbulator to increase the velocity and turbulence of the water near the heat transfer surface. The turbulator may also be designed to minimize the volume of water contained within the server so that the water may be quickly cleared for repairs. The CPU typically includes an air-cooled heat exchanger with fins and a fan located nearby to provide air-cooling. The temperature of the CPU may control the fan so that as it gets hotter, the fan increases in speed. The liquid flow rate may be determined by the acceptable temperature rise of the liquid and the power dissipated by the CPU.

[0005] For a typical CPU that puts out 100 watts, a stream of water at 150 cc/minute will result in a temperature rise of approximately 10 C. A typical air cooled heat exchanger may have a thermal resistance of 0.15 C/watt. The liquid cooled heat exchanger may have a thermal resistance of 0.05 C/watt. By adjusting the position of the water-cooled heat exchanger within the assembly the thermal resistance from the air to the water and the

[0006] CPU may be suitably controlled so as to provide optimal cooling for the air in the data center and the CPU chip. In some cases, multiple passages may be used to cool both the fins and the processor. The temperature differential from the CPU case to the water should be of the same order as the temperature rise of the liquid as it flows through the heat exchanger. The heat exchanger should have a pressure drop of approximately 4 in Hg so that the system will work properly on a hot day in a high altitude location, where the difference between the local atmospheric pressure and the vapor pressure of the hot water can be only 8 inches Hg. The remainder of the pressure drop can be used for plumbing to and from the heat exchanger and the pump, including head loss, elevation changes, and increases in flow resistance due to fouling.

[0007] The fan which is connected to the CPU heat exchanger may also be used to cool the interior of the computer by transferring heat from the air inside the computer to the water so that other components within the server enclosure may be cooled with or without the use of external air flow—i.e., the computer may be sealed. The speed of the fan may be adjusted to remove additional heat from the air inside the server enclosure of the data center as required to minimize the overall power consumption of the data center. The overall power consumption versus fan speed may be determined based on the power consumption of the air conditioning system vs. temperature in the data center and the power consumption of the CPU vs. temperature. CMOS based processors use more energy as the temperature of the processor goes up, due to leakage currents. The air conditioning system uses additional power depending on the temperature of the data center and the heat removal. This increase is generally linear; with higher temperature require proportionally higher air conditioning power. The CPU uses additional power depending on the temperature of the processor due to leakage currents, with the leakage currents increasing exponentially as the processor at the higher end of the temperature. By controlling the flow rate of liquid and air through the heat exchanger, and by adjusting the position of the liquid heat exchanger in the overall assembly consisting of a base and fins, the overall power required for the data center can be decreased. This flow of heat may be suitably analyzed using an electrical analog as shown in FIG. **7**.

[0008] The water reservoir, which supplies water to the heat exchanger, preferably has biocidal and anticorrosive agents to prevent fouling of the heat exchanger.

[0009] The plumbing to and from the server may be designed for a low pressure drop so that the majority of the pressure drop occurs through the heat exchanger. In general, air will be dissolved in the liquid, so that as the liquid is subjected to low pressure and heat, some of the air will come out of the liquid. The system must be designed to pump this out and the plumbing from the heat exchanger may be of larger cross sectional area than the plumbing to the heat exchanger. This has the added benefit of reducing the chance for misconnected plumbing.

[0010] Each server may be fitted with pressure regulator to control the pressure drop across the server, depending on it cooling requirements and a filter may be used after the cooling tower and before the heat exchanger to prevent clogging of the heat exchanger passages. Liquid coolant with chemical additives may be used to prevent fouling of the heat exchanger with biological films and to prevent corrosion. The internal heat exchanger passages may be plated or anodized to prevent corrosion.

[0011] A vacuum reservoir may be located at each server rack, and it may have a float actuated air release to allow for the release of any accumulation of air. Vacuum lines may connect back to a centrally located vacuum sink.

[0012] Each server or server rack may be connected with a dry disconnect system that allows for the automatic draining of the server system. The connector may utilize a sacrificial metal, such as zinc or utilize electrical potential to prevent corrosion inside the CPU heat exchanger. Water would be the best heat exchange fluid due to its low viscosity and high heat capacity. Perfluorocarbons or avionics cooling fluids may also be used. Tap water which has a slight alkaline content that may reduce the corrosion rate for copper and brass heat exchangers.

[0013] The heat exchanger may use a helical flow pattern to put a long path into a short passage. This helical flow passage may have multiple starts, so as to allow for increased flow in a small passage. This may be accomplished by placing a threaded rod in a metal tube so that the flow must take a long path through the heat exchanger at a high velocity. This has the added benefit of reducing the volume of water in the heat exchanger, thereby reducing the amount of water that needs to be cleared to service the heat exchanger. Alternatively, a rod with a tortuous path in relief may be used to displace fluid in the center part of the passage and thereby increase the water flow and turbulence.

[0014] The rod and cylinder may be square, cylindrical, conical, triangular, hexagonal, or any other appropriate shape. The turbulator may be designed so that some of the water flows over the flow passages in an axial direction. This axial flow will interact with the helical flow to provide swirl in the heat transfer passages in order to increase heat transfer. In addition, the axial flow will reduce the flow resistance of the heat exchanger. This arrangement may be particularly useful in situations where the flow is laminar or nearly laminar. For high power dissipation systems, or for additional reliability, multiple parallel turbulators may be used.

[0015] Although a CPU is described, this system maybe used to cool any electronic component. Although water is described, any coolant may be used instead of or in addition to water. Although the system is described as using water for evaporation and for cooling, a liquid to liquid heat exchanger may be used to transfer heat from an evaporative system to a closed system so that a non-corrosive or non-conductive coolant may be used for the CPUs. This may be used in the case of evaporative coolers which use salt water or reclaimed water, for example. For low temperature operation, as in

[0016] Northern latitudes, a radiator, fan and glycol system may be used to reject the heat and prevent freezing of the coolant. Since CPUs can get up to 60-70 C, water can be heated to 50 C and used for hot water service. The water used for cooling the computers may be kept at a temperature higher than the dew point of the air in the data center to prevent condensation on the plumbing or the heat exchangers.

[0017] Any leakage in the system may be detected by monitoring the cycle time of a pump used to remove air from the system. If the pump is cycling on too often, then a leak is indicated. The leak may be discovered by pulling a vacuum on each server and measuring the decrease in vacuum over time. A simple hand operated vacuum pump may be used for this type of testing.

[0018] The system may use a pump with a reservoir to supply fluid to all the heat exchangers. During a shutdown procedure, the pump may evacuate the system; purge it with air and store the fluid until such time as the liquid cooling system is reactivated. During a reactivation procedure, the pump control system may apply a vacuum or a pressure to the system, check to see if the fluid system loses vacuum and then start pumping again, based on the rate of change of the system pressure.

[0019] The coolant used for the computers may be separate from the cooling used for other systems. In this case the heat can be transferred from one system to another using a plate type heat exchanger in a separate cooling loop.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1**A is a perspective view of turbulator and flow passage with a rectangular cross section and a single entry flow passage.

[0021] FIG. **1**B is a top view of turbulator with a rectangular cross section and a single entry flow passage.

[0022] FIG. **1**C is a side view of turbulator with a rectangular cross section and a single entry flow passage.

[0023] FIG. **2** is a top view of turbulator with a rectangular cross section and a double entry flow passage.

[0024] FIG. **3** is a side view of turbulator with a circular cross section and a single entry flow passage.

[0025] FIG. **4**A is an isometric exploded view of a typical air and water cooled heat exchanger with turbulator near the heat source

[0026] FIG. **4**B shows how the liquid coolant may be connected to the heat sink without changing the footprint of the heat sink by removing a few fins and adding a fluid connection.

[0027] FIG. **5** is a side view of a typical air and water cooled heat exchanger with turbulator near the fins.

[0028] FIG. **6** is a section view of a typical air and water cooled heat exchanger with turbulators in the fins.

[0029] FIG. **7** is a diagram showing the heat flow in a server environment which uses a liquid and air cooled heat sink.

[0030] FIG. **8** is a perspective view of a turbulator with a circular cross section and a double entry flow passage.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0031] The following detailed description presents a description of certain example embodiments of the present invention. In this description, reference is made to the drawings wherein like parts are designated with like numerals throughout.

[0032] Referring to the example embodiment shown in FIGS. **1**A, **1**B and **1**C, a turbulator **1** is made with a helical flow passage which forces the flow to go diagonally across one face of the interior of a rectangular heat exchange tube **2** and then across to the other side of said passage, where the flow goes diagonally across the and then back to the previous side. The flow passage is fed with a fitting **3**, which may include a hose barb.

[0033] Referring to FIG. **2**, an alternate turbulator forms a double entry helical flow path. This design allow for more flow at a given pressure than the design in FIG. **1**, in that is uses two parallel flow paths. The use of two paths, instead of one larger, but rectangular path, increases the velocity of the fluid and makes the device resistant to clogging. Also, it reduces the tendency of the flow to short circuit, as in the case of a larger but rectangular flow path, wherein the flow goes directly from one corner to the other and leaves areas of flow recirculation.

[0034] Referring to FIG. **3**, in this case a circular turbulator is used inside of a circular tube. This may be easily constructed by placing a threaded rod in a tube with a close tolerance. This type of design lends itself to use in some of the embodiment described below, in which the heat exchanger is embedded in the fins in order to reduce the thermal resistance to the air.

[0035] Referring to FIG. **4**A, in this embodiment, the heat exchanger tube **2** is soldered into a slot in the base plate **32** of the heat sink **30**, thereby reducing the thermal resistance from the CPU to the liquid. The turbulator **1** enhances the heat transfer from the liquid to the base of the heat sink and to the top of the CPU (not shown).

[0036] Referring to FIG. **4**B, a fitting, **31** is used to connect to a fluid supply and return system so that the cooling system can be connected without affecting the mechanical attachment of the heat sink to the CPU or circuit board. The path of the heat exchange tubes is shown by dashed line **33**.

[0037] Referring to FIG. **5**, in this case the heat exchanger tube **2** is positioned on the top of the heat sink base plate **32** . In this configuration, the thermal resistance from the CPU to the liquid coolant greater than is less than in the design in FIG. **4**A and B However, the thermal resistance from the liquid to the air is reduced.

[0038] Referring to FIG. **6**, the heat exchanger tubes **2** are placed away from the base plate, **32** in order to further reduce the thermal resistance from the liquid coolant to the air. A manifold, **41**, is used to distribute the coolant to the two heat exchanger tubes **42** and **43**. The distance from the base plate to of the tubes may be adjusted in order to adjust the thermal resistance from the liquid coolant to the air and from the CPU to the liquid coolant.

[0039] Referring to FIG. **7** a thermal model of the system is shown. In this model, the thermal resistance from the CPU to the liquid and the air, and from the air to the liquid is illustrated. By means of the prior embodiments, the thermal resistance from the heat sink to air, the CPU to the heat sink, the heat sink to the liquid and the air to the liquid may be adjusted to minimize the overall power consumption of the data center. For example, increasing the number or area of the fins, which is well known in the art, may decrease the thermal resistance from the heat sink to the air. The thermal resistance from the air to the liquid may be decreased by placing the liquid heat exchanger closer to the center of the fins. Heat pipes may also be used to control the flow of heat.

[0040] FIG. **8** illustrates yet another type of turbulator with a circular cross section. The turbulator forms a double entry helical flow path. To illustrate these paths,

[0041] FIG. **8** has a black shading **50** that illustrates one path, while the non-shaded area **52** illustrates the independent second path. This design allow for more flow at a given pressure than the design in FIG. **1**, in that is uses two parallel flow paths. The use of two paths, instead of one larger path increases the velocity of the fluid and makes the device resistant to clogging. Also, the dual path and circular cross section reduces the tendency of the flow to short circuit, thus maintaining the flow in thermal contact with the heat exchange tube and increasing cooling efficiency.

[0042] While the invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present invention as would be understood to those in the art as equivalent and the scope and context of the present invention is to be interpreted as including such equivalents and construed in accordance with the claims appended hereto.

1. A liquid cooling system for cooling an electrical device, comprising:

a fluid-containing heat exchanger tube thermally coupled to said electrical device;

a turbulator within said heat exchanger tube;

said turbulator configured to force the fluid in a path with length more than twice the largest dimension of said heat exchanger tube.

wherein said turbulator reduces a flow path cross sectional area to less than 50% of the cross sectional area of the original tube.

* * * * *