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APPARATUS FOR LIQUID COOLING OF SPECIFIC COMPUTER COMPONENTS

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The present invention relates to apparatus for liquid cooling by conduction of specific computer components mounted within a housing for a computer in order to reduce the operating temperature of such components.

As certain components for computers, such as microprocessors or hard disk drives become more powerful and complex, while maintaining compact size, more effective thermal management becomes necessary in order to maintain desirable operating temperatures. It is well known that according to the Arrhenius equation, there is an exponential increase in failure rates with incremental increases in operating temperatures. For example, assuming a 1.0 eV activation energy, the failure rate doubles for every 10° rise in operating temperature. Therefore, increases in power of computer chips such as the Pentium® requires more effective heat management techniques to prevent undesirable rises in operating temperatures.

It is known to apply air-cooled fin modules directly to electronic components in order to dissipate heat through conduction by use of finned heat exchangers and convection with such heat exchangers being cooled by air flow. For example, Intel's 486 microprocessor was cooled by a conformal finned heat exchanger, and Intel's Pentium® chip has been cooled by finned type heat exchangers which have surface area extending beyond the actual contact surface area of the Pentium®, sometimes known as extended surface heat exchangers. The operating power of certain components such as newer versions of Pentium® chips of Intel has reached levels which require high volumes of forced ambient air to dissipate generated heat; however, forced air to cool finned modules have limitations in that there may be an upper limit to volumetric flow of cooling air due to noise or other factors such as increased power requirements.

Cooling systems other than finned surface area exchangers are currently known in the prior art. For examples Peltier coolers and heat pipes are known. But, the potential height of Peltier coolers as well as the requirement for extra cooling load due to inherent inefficiencies reduce the probability for successful application to high heat load components. And, heat pipes have heat transfer capacity limitations due primarily to losses in realizing connection to hot and cold thermodynamic reservoirs, but also due to limitations of heat transport due to internal design limits.

It is also known to use cooling plates for circulating liquid coolant, which plates are mounted in contact with various power modules such as transistors, diodes and rectifiers. For example, the EG&G Components Division of Wakefield Engineering of Wakefield, Massachusetts manufactures sheet plates which are bent to conform, that is, crimped about cooling tubes and water-cooled solid copper blocks designed to cool pressure mounted rectifiers and SCR's dissipating up to 2 kw per device. The Wakefield cooled plates have several disadvantages in that there is significant thermal resistance across the interface between the copper tube and the aluminum plate, and in that crimping of tubes

in such a manner have been found to lead to variations in cooling of up to 50 per cent.

A number of prior art patents are directed to the use of liquid coolant to cool electronic components, particularly in large main frame type computers. U.S. Patent No. 5,159,529 utilizes a plastic internal cooling core having mounted to it one or more cooling plates of copper to receive various electronic components. However, the attachment of cooling plates of copper to a plastic core may cause possible leak problems due to material incompatibility. U.S. Patent No. 5,144,532 discloses the use of two oppositely positioned liquid cooling plates which are in contact with printed circuits positioned on opposite sides of a multi-layer printed circuit board. U.S. Patent No. 4,748,495 discloses a liquid cooling module for a plurality of integrated circuit chips arrayed in uneven height wherein cooling fluid is routed either through a group of heat sinks or independently through each of a number of heat sinks. And, U.S. Patent No. 4,758,926 discloses utilizing heat sinks having microchannels to receive cooling fluid for cooling chips.

While the prior art encompasses the general use of cooling fluid or coolant to cool electronic components, there remains a need to develop a high capacity cooling system for mounting within computer housings for desktop and server size computers where the cooling system is in direct contact with the most powerful and highest heat generating electronic components, such as more recent and more powerful versions of the Pentium® processor and hard disk drives. It is accordingly an object of this invention to provide a cooling system specifically directed to such components.

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In accordance with various embodiments of this invention, apparatus is provided for transferring heat from high heat generating electronic components such as advanced, high powered computer chips and hard disk drives. In one

embodiment, such apparatus includes a generally rectangular chassis having a plurality of components including a mother board, with a processor chip being mounted in one of the processor slots on the mother board. A heat exchange assembly includes a power supply mounted in one corner of the chassis having
5 a fan mounted adjacent to the power supply. The heat exchange assembly is provided for dissipating heat generated by the chip including an air to liquid heat exchanger mounted on the chassis adjacent to the fan, a pump mounted on the chassis at a convenient point and a heat transfer plate having a configuration substantially identical to the bottom surface of the high heat generating chip.
10 The heat transfer plate is connected to the air side heat exchanger and pump by suitable tubing lines so that a liquid coolant can be transferred to the heat transfer plate in order to remove heat from the high heat generating chip, with the heated coolant being cooled in the air side heat exchanger and returned by the pump to the heat transfer plate in a continuous fashion.

15 In another embodiment of this invention, apparatus is provided for cooling an operating hard disk drive, including a generally U-shaped heat exchange clip for resilient mounting onto the sides of the hard disk drive container. The U-shaped clip has external liquid coolant flow loops attached on the outside of the clip in order to transfer heat from the hard disk drive. In
20 another embodiment of cooling for an individual hard disk drive, apparatus includes a generally rectangular heat transfer plate having substantially the same dimensions as a surface of a hard disk drive container for transferring heat from such container.

And, further apparatus is provided for transferring heat from a vertical
25 array or stack of hard disk drive units. Such apparatus includes one or more panels mounted between adjacent, vertically positioned hard disk drive units in order to remove heat from adjacent units simultaneously.

This summary of the invention is intended as a general description of the attributes of this invention, which will now be described in more detail in the

detailed description, with the claims to follow setting forth the subject matter sought to be patented.

Fig. 1 is a schematic view of a computer illustrating the preferred
5 embodiment of this invention for providing a liquid cooling medium to a high heat generating processor;

Fig. 2 is a schematic view illustrating a heat exchange plate for mounting onto a high heat generating processor;

Fig. 3 is a side view illustrating an air to liquid heat exchanger for cooling
10 liquid flowing from the heat exchange plate of Fig. 2;

Fig. 4 is a perspective view of a clip-on heat exchanger for providing heat exchange liquid coolant to a hard disk drive;

Fig. 5 is a perspective view of the rear side of the clip-on hard disk drive heat exchanger of Fig. 4;

15 Fig. 6 is a perspective view of a heat transfer plate for mounting on the surface of a hard disk drive; and

Fig. 7 is a perspective view of the use of heat exchange panels for insertion between adjacent, vertically stacked hard disk drive units.

20 Referring to the drawings and in particular to Figs. 1-3, apparatus generally designated as A is illustrated for continuously cooling a high heat generating component P such as the Pentium® manufactured by Intel Corporation, which generates high heat due to its power requirements. When the Pentium® chip was first developed by Intel, Intel proposed that the
25 Pentium® chip be cooled by a combination of a heat sink and air flow, with the size of the heat sink and the amount of air flow being interrelated. Public specifications for early versions of the Pentium® chip included maximum power

for a 66 MHZ Pentium® processor of a PGA package type of 16W, having a package size of 2.16" x 2.16" and a maximum case operating temperature of 70°C. Intel further disclosed as specifications that the maximum device junction temperature for such a Pentium® processor was 90°C.

5 Within a typical computer housing, it is known that ambient air should be in the range of 40°C to 45°C, ambient air being defined as the temperature of the undistributed ambient air surrounding the Pentium® package. For Intel, ambient temperature was typically measured at 12 inches upstream from the package under investigation and in a system environment, ambient temperature
10 was defined as the temperature of the air upstream to the package and in its close vicinity.

 With the advent of newer generations of the Pentium® processor and other high operating temperature or high heat generating chips such as application specific integrated circuits (ASICs), which will be collectively referred
15 to hereinafter as "high heat generating processors" or "high operating temperature chips," it is becoming increasingly difficult to maintain such operating processors within desired operating temperature limits utilizing only a combination of heat sinks or finned heat exchangers subjected to air flow. Apparatus A of this invention is directed to a cooling system utilizing liquid as a coolant for
20 specifically maintaining high operating temperature processors or chips within manufacturer's specified limits. Further, it is known that chip manufacturers typically reject or sell at reduced prices chips which exceed operating temperature specifications. Utilizing apparatus A of this invention may allow use of previously rejected chips which can be purchased at reduced rates.

25 Referring to Fig. 1, a computer housing generally designated as 10 is illustrated. The housing 10 is in a rectangular box form as is well-known in the prior art. The exemplary housing 10 includes a bottom 11, a first set of opposing sides 12a and 12b and a second set of opposing sides 14a and 14b, all of which are interconnected or formed integrally with the bottom 11. A chassis generally

designated as 13 is mounted within the housing 10 in a known manner. The chassis 13 is generally rectangular so that the chassis has opposing sides (not shown, but parallel to and slightly smaller in dimension as the sides of the computer housing) to conform to the computer housing bottom 11 and sides
5 12a-b and 14a-b and includes mother board 15.

As is known in the art, the mother board 15 is positioned adjacent to bottom 11 of housing 10 to mount the various computer components which are utilized as known in the art. All the components necessary for a fully operating computer will not be described herein but are fully known to those of ordinary
10 skill in the field of computer design. The components which will be specifically identified herein are those specifically relevant to this invention.

The mother board 15 includes a series of slot mountings (not shown but known in the art) which mount a series of "daughter" boards including boards such as microprocessor board 16 which actually mounts the Pentium® or other
15 high heat generating processor. The advantage of mounting the principal high heat generating processor P onto a removable board 16 is that the computer may be enhanced by exchanging board 16 for a board containing a new and improved high heat generating chip. Other daughter boards such as a peripheral component interface board or a video interface board are mounted and identified
20 as 17 and 18. It is also common to mount the processor chip in zero insertion force (ZIF) or low insertion force (LIF) sockets. Housing door or opening 19 mounts one or more bays for receiving floppy disk drives or compact disk drives as is known in the art. The rectangular structure generally designated at 20 is the mounting location for one or more such peripheral component units.

25 A power supply 21 is mounted in the corner of the housing formed by sides 14a and 12b such that no coolant leak could flow into the power supply primary side under any operating condition due to gravity or entrainment in the air flow. A computer cooling fan 22 is mounted adjacent to the power supply 21.

A series of slots 23 are formed in the side or face 14b in order to allow for the in flow or out flow of air for circulation through the housing.

Apparatus A of this invention continuously provides liquid coolant to the high operating temperature chip P and includes a pump generally designated as 30, an air-side heat exchanger generally designated as 32 and a heat transfer plate 34. The pump 30, which may be mounted at any convenient location within the confines of the chassis 13, provides a closed loop liquid coolant circulation system for pumping coolant between the air-side heat exchanger 32 and the plate heat exchanger 34. The air side heat exchanger 32 is illustrated in detail in Fig. 3. The air side heat exchanger 32 can be any of a number of commercially available heat exchangers. In the current preferred embodiment heat exchanger 32 of Fig. 3 may be similar to a 720 series heat exchanger having a transfer capacity up to 18 kw sold by EG&G Division of Wakefield Engineering of Wakefield, Massachusetts. The series 720 heat exchanger 32 utilizes copper tubing 32a which extends from inlet 32c and is formed in a serpentine configuration which exits the unit at outlet 32b. A frame for mounting the serpentine configuration of the copper tubing 32a is generally rectangular in configuration and designated by the number 33, and is made of aluminum. The air side fins 32d are mounted within the aluminum frame 33 and attached to the serpentine configuration of copper tubing in a known manner. The unit comes with an available standard Rotron Muffin Fan tm XL Model No. MX2A3 or another fan unit 22 may be used as is known in the art. In any event, it is desirable to mount the air side heat exchanger 32 immediately adjacent to the fan unit 22 for greatest heat transfer efficiency to reduce the temperature of liquid coolant flowing therethrough. The pump 30 to be utilized should have a diameter of no greater than 2.5 inches and a length of no greater than 5.0 inches. The pump 30 should have a flammability rating of UL94 94V-2 and a UL motor overload and lock rotor rating of UL 1950. For purposes of

definition, the pump 30 has low pressure entry port 30a and a high pressure exit port 30b.

The cooling plate 34 is illustrated schematically in Fig. 2. The cooling plate 34 is a rectangular block of solid copper which receives a brass tubing line 35 at its outlet 34b and brass tubing line 36 at its inlet 34c. The brass tubing lines 35 and 36 are shown in dashed lines in Fig. 1 since the pump may be located at any available location within the confines of the chassis 13. The copper block 34 is shown to have a U-shaped bore portion generally designated as 34a drilled through the block or otherwise formed. However, other configurations for the flow, including a serpentine flow path having multiple bores extending in the long direction of the block may be utilized in order to effect greater heat transfer. The overall dimensions of the copper block in terms of length and width are to be designed to conform to the length and width of the alloy material bottom surface or ceramic undersurface of the Pentium® chip or other bottom surface of a high operating temperature chip. The topography of the block surface to be in contact with the bottom surface of a high heat generating chip can be machined to conform to the bottom surface of this chip with interstitial application of thermal grease or equivalent as known by the art to avoid air pockets. Rather than utilize a solid copper block, it is within the scope of this invention to utilize as a cooling plate 34 a hollow block having bottom, top and four sides formed of copper or brass with one or more internal baffles running lengthwise part of the length of the housing to partition the housing into multiple chambers for purposes of providing fluid communication with the inlet tube 36 and the outlet tube 35. The tubing should be brass or fire-resistant plastic and rated to required operating conditions, and should have a flammability rating of UL62 VW-1.

The liquid coolant may be water, or a mixture of 50 percent ethylene glycol and water with known corrosion inhibitors. The liquid system will utilize

connectors known in the art to provide a closed coolant system which is sealed for life and is not field serviceable.

It is known that the electronic components mounted on the chassis typically raise the ambient temperature within the computer housing 10 about 10° C. It is further known that high heat generating chips such as the Pentium®
5 have an operating temperature range of about 60-70° C. The apparatus A of this invention is designed to cool the chip P to an operating temperature within the range of about 55° C in order to be able to use chips which currently are out of specification of certain chip manufacturers. This is accomplished by designing
10 the size of the heat exchanger 32 and flow rate of the pump 30, taking into consideration the effective heat transfer of the cooling plate 34, such that sufficient heat will be transferred from the operating chip P to reduce the operating temperature to about 55° C for worst case operating conditions, that is, to about 5° C below the bottom of the temperature operating range of the
15 chip. The 55°C assumes a room ambient temperature of 40°C. The required flow rate will vary depending upon the particular processors, ASIC and/or hard drive cooled, but it is believed that the flow rate will be less than the prior art uses of liquid cooling.

Referring to Figs. 4-6, apparatuses B-1 and B-2 are illustrated and
20 provided for providing liquid coolant for reducing the operating temperature of hard disk drives. The hard disk drives such as drive D-1 illustrated in Fig. 4 and drive D-2 illustrated in Fig. 6 have become commercially standard components in their mounting pattern and envelope. The drives D-1 and D-2 are mounted inside computer housings either alone or in densely stacked arrangements (to be
25 discussed with respect to Fig. 7). Typically, the hard disk drives are cooled by air flow without heat sink provisions due to the type of packaging. Hard disk drives such as D-1 and D-2 come in two basic sizes, "half height" and "full height." The only difference is that the half height hard disk drive is approximately 1 inch high and the full height hard disk drive is approximately

1.63 inches high. Hard disk drive assemblies are basically built of a steel container with a single printed wiring board (PWB) such as designated as 50 in Figs. 4 and 6 being screwed intimately to the bottom 51a of the hard disk drive housing generally designated as 51. The other surfaces of the hard disk drive housing 51 include top 51b, front and back sides 51c and 51d, respectively, and opposing sides 51e and 51f. As is well-known in the art, the hard disk drive container 51 contains a set of hard drive disks mounted on a spindle which rotates at many thousands of rpm. The rotating action results in making the internal hard drive container environment into a uniform temperature or what may be termed a "well-stirred vessel." Hard disk drives such as D-1 and D-2 contain several temperature sensitive devices including but not limited to the motor bearings.

It is known to cool hard disk drives in part through conduction cooling through their mounting rails, a techniques which is limited in efficiency due to the interface conductance loss through the rails and loss due to conduction throughout the length of the rails.

Referring to Fig. 4, apparatus B-1 is a clip-on heat exchanger for resilient mounting onto opposing surfaces of a hard disk drive D-1 unit housing 51. The clip-on heat exchanger 60 is formed of a generally U-shaped spring clip 60 made of beryllium copper, phosphor bronze or other suitable metal. The U-shaped spring clip 60 is formed of first and second clip arms 60a and 60b which are integrally joined to the clip base or back 60c through two curved or arcuate integrally formed yieldable sections 60d and 60e. The U-shaped heat exchanger clip 60 is thus formed with sides 60a and 60b which are easily and resiliently expandable apart for insertion onto the sides 51e and 51f of the disk drive housing 51 and thereafter are held in place due to the resilient compressibility of the spring action of the clip itself.

Referring to Figs. 4-5, the U-shaped spring clip includes openings 60f and 60g positioned in the arcuate sections 60d and 60e. Tubing inlet 62 and tubing

flow outlet 63 are mounted with the heat exchange clip back 60c and sides 60a and 60b in order to cool the heat exchange clip itself and thereby through conduction absorb heat from the disk drive housing 51. Tubing inlet line 62 passes through a junction 64 having a Y-shaped connection (not shown) to divide the inlet line into first and second inlet line portions 62a and 62b. Tubing outlet line 63 is divided by a Y-shaped connection into tubing outlet line portions 63a and 63b. Inlet lines 62a and 62b extend through heat exchange clip openings 60f and 60g, respectively, and extend longitudinally along the length of each of the outer surfaces of sides 60b and 60a. The tubing portions 62a and 62b are attached to the sides 60a and 60b by brazing at points 65. The tubing inlet lines such as 62a makes U-turn at section 62c and joins return coolant line 63a, which extends back to coolant outlet line 63. The heat exchange clip coolant inlet line 62 extends to the pump outlet for a pump such as the pump 30 of Fig. 1, and the heat exchange clip coolant outlet line 63 extends to the inlet of the air side exchanger such as 32 so that the heat exchanger 32 in the pump 30 is part of the overall hard drive coolant system of Figs. 4-5 for continuously removing heat from the operating hard disk drive.

Referring now to Fig. 6, a hard disk drive D-2 is illustrated. Drive D-2 has a housing identical to housing 51 of drive D-1 except that drive D-2 is attached on one or more of its sides such as 51e to mountings within the computer housing such that it is necessary to provide apparatus B-2 to provide cooling to the hard disk drive. Apparatus B-2 includes a copper plate 70 which is rectangular in configuration and has a length and width which matches the top surface 51b of hard drive D-2. Coolant inlet line portion 71a extends from an outlet line from the pump 30 (Fig. 1) other suitable pump and is mounted onto the top of the cooling plate 70 by brazing at various points 65 as shown in Fig. 6 and extends in a generally rectangular pattern around the perimeter of the cooling plate 70 and terminates in an outlet portion generally designated 71b integrally formed with the inlet portion, such outlet portion 71b extending to an

inlet to the air side heat exchanger 32 or other suitable air side heat exchanger, so that the pump 30 and air side heat exchanger of Fig. 1 form part of the heat exchange system B-2 of Fig. 6. One or more retainer clips generally designated as 72 are mounted on one or more sides such as 51c, 51e and/or 51f of the hard disk drive D-2 in order to retain the cold or cooling plate 70 in position on the top surface 51b of the disk drive housing 51.

Referring to Fig. 7, apparatus B-3 is provided for cooling vertical array of hard disk drives D-3, D-4, D-5 and D-6, which are vertically stacked upon each other and mounted to suitable computer mountings by screw holes 80 such as well known rail-type mountings (not shown). The vertical array of hard disk drives D-3 through D-6 will generate substantial heat which cannot be suitably cooled to desired operating temperatures through the use of conventional heat sinks and air cooling. Each of the hard disk drives D-3 through D-6 include a generally rectangular, box-like housing or container having a top surface, a bottom surface and opposing sides surfaces and thus the same designation for each housing for each of the containers for drive units D-3 through D-6 may be used. Air cooling is undesirable as a technique due to the high volumes of air necessary to cool, which would require undesirable reliability risk due to possible fan failure and which will cause acoustical problems, also. The cooling system B-3 is provided for interposition or sandwiching between adjoining hard disk drives such as D-3 and D-4 for providing for conductive heat transfer of heat from adjacent disk drives to a series of flexible heat exchange structures or panels 81.

Each of the flexible heat exchange structures 81 is made of a hollow, relatively thin, sheet-like panel in rectangular form and is filled with a coolant liquid such as a mixture of 50% water and 50% ethylene glycol. The flexible heat exchange structure 81 has a peripheral seal section 81a which extends about the rectangular periphery to form a cavity or chamber therein. The interior of the flexible heat exchange structure is formed of five flexible body layers which

include, from top to bottom, a top layer. a middle layer and a bottom layer of a polyamide film material, representatively a material manufactured by the Dupont Company under the name "KAPTON," with intervening layers of an FEP fluorocarbon film material, representatively a material manufactured by the Dupont Company under the tradename "TEFLON." Passages are provided through the central area between the two sheets of fluorocarbon film material by providing round interbonded sections 81b at spaced locations in order to provide a generally U-shaped flow path 82 through the flexible heat exchange panel or structure 81. The points of film attachment 81b also serve to hold the outer sheets against undesirable expansion or ballooning, which may provide undesired forces against the printed wiring board 50 side of the drives. Instead, the force can be controlled to provide only beneficial heat transfer pressure to enhance the heat transfer contact with the surface of the hard disk drives. The location of the round interbonded sections may be varied in order to provide different flow paths but in the embodiment illustrated, the interbonded sections 81b are located at four points in a line along three lines running a longitudinal direction of the pad 81.

For further description of the manufacture of such a flexible heat exchange panel, Applicant incorporates by reference U. S. application serial number 08/674,081 listing as inventors Messrs. Daniel N. Donahoe and Michael T. Gill, which patent application was filed on July 17, 1996 and assigned to the same assignee as herein, Compaq Computer Corporation. While the entire disclosure, specification, claims and drawings are incorporated herein by reference for purposes of enabling description and for support for claiming, Applicant specifically directs attention to the disclosure relating to Figs. 3-7, and to the description of the cross-sectional flow passages found on pages 9-12, and referring in particular to Figs. 3 and 4. It is also feasible to use a more simplified panel structure having two adjoining layers of suitable flexible plastic material

sealed at their periphery and having multiple points where the sheets are heat welded together internally of the sealed rim.

Each of the flexible heat exchange panels 81 includes a coolant entrance or inlet 81c and a coolant outlet 81d. With the panels 81 positioned or sandwiched between adjacently stacked hard disk drives such as D-3 and D-4, the coolant flow outlets 81d of each panel 81 are connected to a central return manifold 85 through connections 85a, 85b and 85c. A similar inlet manifold 87 connects together the inlets 81c for each of the interposed or sandwiched flexible cooling panels 81. The inlet manifold 87 is then attached to the outlet to a suitable pump such as the pump 30 of Fig. 1. The outlet manifold 85 is suitably connected to the inlet of an air side heat exchanger such as the air side heat exchanger 32 disclosed in Figs. 1 and 3.

The expansion of the panels during operation, as the result of fluid pressure, has another beneficial feature, which is that the drives are held more tightly in position during operation; and, when the panels are deflated, the drives are more easily removed.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the details of the illustrated apparatus and construction and method of operation may be made without departing from the spirit of the invention. For example, it is within the scope of this invention to combine the various heat transfer embodiments of this invention for use within a single computer. Apparatus A of Figs. 1-3 can be used to cool multiple chips by properly sizing the pump 30, fan 22 and the air side heat exchanger 32 to provide suitable cooled liquid coolant to more than one heat transfer plate 34 simultaneously. Further, the pump 30, fan 22 and air side heat exchanger 32 may be suitably sized to cool the hard disk drive housing 51 using the U-shaped clip 60 of apparatus B-1 of Figs. 4-5 or using the heat transfer plate 70 of apparatus B-2 of Fig. 6 in conjunction with the system of Figs. 1-3. Or, the system B-3 for cooling the vertical array of disk drives D-3

through D-6 of Fig. 7 can be combined with the cooling system A of Fig. 1-3. Further, disk cooling apparatus B-1 and B-2 can be used with the air side heat exchanger 32 and pump 30 of Figs. 1-2. Or, any other combination of any of A, B-1, B-2 and/or B-3 can be used with a single pump, air side heat exchange
5 assembly.



CLAIMS

What is claimed is:

- 1 1. Electronic apparatus comprising:
 - 2 a generally rectangular chassis having first and second sets of
 - 3 opposing sides;
 - 4 a plurality of electronic components mounted with said chassis
 - 5 including a mother board;
 - 6 said mother board having a plurality of extension slots, a processor
 - 7 board mounted in one of said processor slots and having a high heat generating
 - 8 chip mounted thereon;
 - 9 a power supply mounted at the junction of one of said first set of
 - 10 sides and one of said second set of sides of said chassis and having a fan mounted
 - 11 adjacent to said power supply; and
 - 12 a heat exchange assembly for dissipating operating heat generated
 - 13 by said high heat generating chip including:
 - 14 an air to liquid heat exchanger mounted on said chassis adjacent to
 - 15 said fan, said air to liquid heat exchanger having an inlet port and an exit port
 - 16 in fluid communication with a plurality of liquid coolant passageways spaced to
 - 17 receive fan generated air flow in order to reduce the temperature of coolant
 - 18 flowing through said passageways from said inlet port to said exit port;
 - 19 a pump mounted on said chassis, said pump having a low pressure
 - 20 entry port and a high pressure exit port;
 - 21 a heat transfer plate having a configuration substantially identical
 - 22 to the bottom surface of said high heat generating chip and being operatively
 - 23 attached thereto, said heat transfer plate having a liquid coolant inlet and exit
 - 24 port, and having a passageway internally thereof to provide for flow of coolant
 - 25 from said inlet to said exit; and





26 tubing extending between said exit port of said heat transfer plate
27 to said inlet port of said air to liquid heat exchanger and tubing extending
28 between said inlet port of said heat transfer plate and the exit port of said pump.

1 2. Electronic apparatus of claim 1, including:
2 said pump, heat transfer plate, tubing and air side heat exchanger
3 providing a closed system for circulating liquid coolant.

1 3. Electronic apparatus of claim 2, including:
2 said coolant being a mixture of approximately 50 per cent water
3 and approximately 50 per cent ethylene glycol.

1 4. Electronic apparatus of claim 1, wherein:
2 said fan has a rectangular configuration and said air side heat
3 exchange has a substantially similar configuration.

1 5. Electronic apparatus of claim 1, including:
2 said electronic chassis producing an air rise in ambient temperature
3 of 10°C when mounted within a housing for a computer, and said high heat
4 generating chip having a design operating temperature in the range 60-70°C, and
5 said air to liquid heat exchanger providing sufficient change in temperature from
6 said inlet port to said exit port to maintain the operating temperature of said
7 high heat generating chip at about 55°C.

1 6. A computer, comprising:
2 a generally box-like rectangular external housing having a generally
3 rectangular chassis having first and second sets of opposing sides for mounting
4 within said external housing;



5 a plurality of electronic components mounted with said chassis
6 including a mother board;

7 said mother board having a plurality of extension slots;

8 a processor board mounted in one of said processor slots and having
9 a high heat generating chip mounted thereon;

10 a power supply located at the junction of one of said first set of
11 sides and one of said second set of sides of said chassis and having a fan mounted
12 adjacent to said power supply; and

13 a heat exchange assembly for dissipating heat generated by said
14 high heat generating chip including:

15 an air to liquid heat exchanger mounted on said chassis adjacent to
16 said fan, said air to liquid heat exchanger having an inlet port and exit port in
17 fluid communication with a plurality of liquid coolant passageways spaced to
18 receive fan generated air flow in order to reduce the temperature of coolant
19 flowing through said passageways from said inlet port to said exit port;

20 a pump mounted on said chassis, said pump having a low pressure
21 port and a high pressure port;

22 a heat transfer plate having a configuration substantially identical
23 to the bottom surface of said high heat generating chip and being operatively
24 attached thereto, said heat transfer plate having a liquid coolant inlet and exit
25 port, and having a passageway internally thereof to provide for flow of coolant
26 from said inlet to said exit; and

27 tubing extending between said exit port of said heat transfer plate
28 to said inlet port of said air to liquid heat exchanger and tubing extending
29 between said inlet port of said heat transfer plate and the exit port of said pump.

1 7. The computer of claim 6, including:

2 said pump, heat transfer plate, tubing and air side heat exchanger
3 providing a closed coolant system for circulating liquid coolant.





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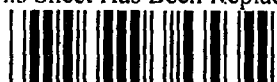
1 8. The computer of claim 7, including:
2 said coolant being a mixture of approximately 50 per cent water
3 and approximately 50 per cent ethylene glycol.

1 9. The computer of claim 6, wherein:
2 said fan has a rectangular configuration and said air side heat
3 exchange has a substantially similar configuration.

1 10. The computer of claim 6, including:
2 said computer external housing having an air rise in ambient
3 temperature of 10°C, and said high heat generating chip having a design
4 operating temperature in the range 60-70°C, and said air to liquid heat exchanger
5 providing sufficient change in temperature from said inlet port to said exit port
6 to maintain the operating temperature of said high heat generating chip at about
7 55°C.

1 11. Electronic apparatus, comprising:
2 a generally rectangular chassis having first and second sets of
3 opposing sides;
4 a plurality of electronic components mounted on said chassis,
5 including a hard disk drive, said hard disk drive having a generally rectangular
6 box-like container;
7 a heat exchange system for said hard disk drive, including:
8 a generally U-shaped heat exchange clip including first and second
9 arms integrally formed with a base;
10 a coolant loop mounted with said U-shaped heat exchange clip, said
11 coolant loop including a first loop section attached to said first arm of said heat
12 exchange chip and a second loop section attached to said second arm of said heat

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13 exchange clip for circulating liquid coolant to absorb heat transferred from said
14 hard disk drive container to said first and second arms of said heat exchange clip;
15 said arms of said U-shaped clip being resiliently formed with said
16 base for insertion over said hard disk drive container in resilient engagement
17 therewith; and
18 a closed circulation system for circulating liquid coolant to said
19 cooling loop mounted on said U-shaped clip and reducing the temperature of
20 said coolant circulating from said cooling loop before circulating said coolant to
21 said cooling loop.

1 12. Electronic apparatus of claim 11, including:
2 said coolant loop first and section sections being formed of tubing
3 for directing the flow of liquid coolant, said coolant loop including first and
4 second inlet tubing sections attached to said base and to said first and second
5 arms of said U-shaped clip, respectively, and first and second outlet tubing
6 sections attached to said base and to said first and second arms of said U-shaped
7 clip, side inlet and outlet sections being interconnected on each of said arms such
8 that liquid coolant is flowable from said first and second inlet sections to said
9 first and second outlet sections in order to absorb heat from said container of
10 said hard disk drive.

1 13. Electronic apparatus of claim 11, comprising:
2 each of said first and second arms of said U-shaped clip has an
3 opening therein, said first loop section and said second loop section extending
4 through said openings in said first arm and said second arm for attachment to
5 the outside surface of each arm.

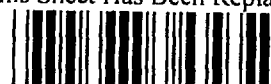
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1 14. Electronic apparatus, comprising:
2 a generally rectangular chassis having first and second sets of
3 opposing sides;
4 a plurality of electronic components mounted on said chassis,
5 including a hard disk drive, said hard disk drive having a generally rectangular
6 box-like container having a top surface, bottom surface and two sets of opposing
7 side surfaces; and
8 a heat exchange apparatus for controlling the operating temperature
9 of said hard disk drive, including:
10 a rectangular heat transfer plate having substantially the same
11 dimensions as a surface of said hard disk drive generally rectangular box-like
12 container, said heat transfer plate being mounted onto said one of said surface
13 of said hard disk drive generally rectangular box-like container;
14 a cooling tubular section being mounted on to said heat transfer
15 plate and extending across said plate in a generally rectangular configuration and
16 having an exit section and an inlet section; and,
17 circulation means operatively connected to said cooling tubular
18 section mounted on said heat transfer plate to reduce the temperature of said
19 coolant exiting said exit section of said cooling tubular section and circulating
20 said coolant at said reduced temperature to said inlet section of said cooling
21 tubular section mounted on said heat transfer plate.

1 15. Electronic apparatus, comprising:
2 a generally rectangular chassis for mounting electronic components;
3 a plurality of hard disk drive units mounted in a vertical array, each
4 of said hard disk drive units having a generally rectangular box-like housing
5 including a rectangular top surface and a rectangular bottom surface;
6 a heat dissipation assembly for said vertical array of hard disk drive
7 units, including:





8 a heat transfer panel mounted between said bottom surface of one
9 hard disk drive housing and said top surface of another hard disk drive housing,
10 said panel having a liquid coolant circulation path for circulating liquid coolant
11 to absorb heat generated during operation of said hard disk drive units; and
12 a coolant circulation assembly continuously removing from said
13 panel coolant which has been heated by said hard disk drive units and for
14 reducing the temperature of said heated coolant and returning said coolant to
15 said panel in order to dissipate heat generated by said hard disk drive units.

1 16. Electronic apparatus of claim 15, wherein:
2 said heat transfer panel is flexible.

1 17. Electronic apparatus of claim 15, including:
2 said heat transfer panel is hollow and is formed from at least two
3 sheets of flexible material arranged in a mutually parallel, facing relationship.

1 18. Electronic apparatus of claim 17, wherein:
2 said hollow heat transfer panel has an inlet opening and an outlet
3 opening; and
4 said coolant circulation assembly includes a pump communicating
5 with said inlet opening, and an air side heat exchanger communicating with said
6 outlet opening.

1 19. Electronic apparatus of claim 15, wherein:
2 said coolant is a mixture of water and ethylene glycol.

1 20. Electronic apparatus of claim 19, wherein:
2 said liquid is a mixture of about fifty percent by volume of water,
3 and about fifty percent by volume of ethylene glycol.





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1 21. Electronic apparatus according to claim 15, including:
2 said heat exchange panel being formed of opposing flexible sheets
3 of material;
4 said heat transfer panel has a peripheral sealed edge forming a
5 hollow cavity therein to receive said coolant.

1 22. Electronic apparatus according to claim 21, including:
2 a plurality to interbonded points within said hollow cavity wherein
3 said opposing flexible sheets are joined together.

1 23. Electronic apparatus according to claim 18, wherein:
2 said heat dissipation assembly includes two or more of said heat
3 transfer panels;
4 an inlet flow manifold in fluid attachment with inlet openings of
5 said two or more heat transfer panels and an outlet flow manifold in fluid
6 attachment with each of said outlet openings of said two or more heat transfer
7 panels; and
8 said inlet and outlet flow manifolds being in fluid communication
9 with said coolant circulation assembly.

1 24. Electronic apparatus according to claim 16, including:
2 said heat transfer panel is expandable during flow of liquid coolant
3 therethrough, and is contractable to allow for greater ease in removal of said disk
4 drive units.

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APPARATUS FOR LIQUID COOLING OF SPECIFIC COMPUTER COMPONENTS
ABSTRACT

Apparatus is provided for a heat transfer assembly for direct attachment to a high heat generating chip, which assembly includes a pump, air side heat exchanger mounted adjacent to a fan and a heat transfer plate which is attached to the high heat generating component for dissipating heat from such component under operating conditions. In another embodiment, apparatus is provided for dissipating heat from a hard disk drive including a U-shaped heat exchange clip resiliently mounted on opposite surfaces of a hard disk drive. In another embodiment, apparatus for dissipating heat from a hard disk drive includes a generally rectangular plate for mounting on the top or bottom of the hard disk drive. And, in another embodiment, apparatus is provided transferring heat from a vertical array of hard disk drives, which apparatus includes one or more panels interposed between adjacent vertically disposed hard disk drives.
(Fig. 1)

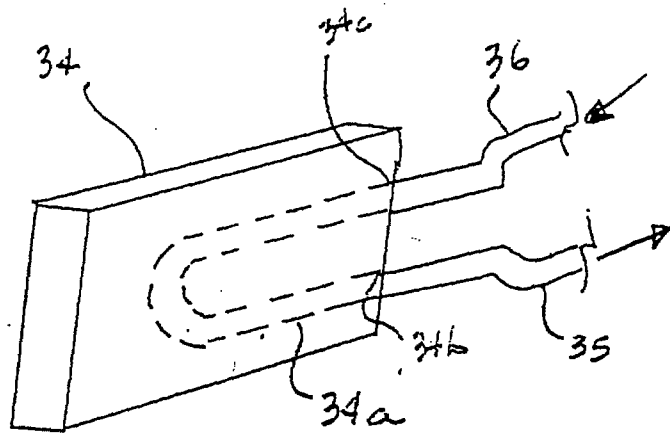


Fig. 2

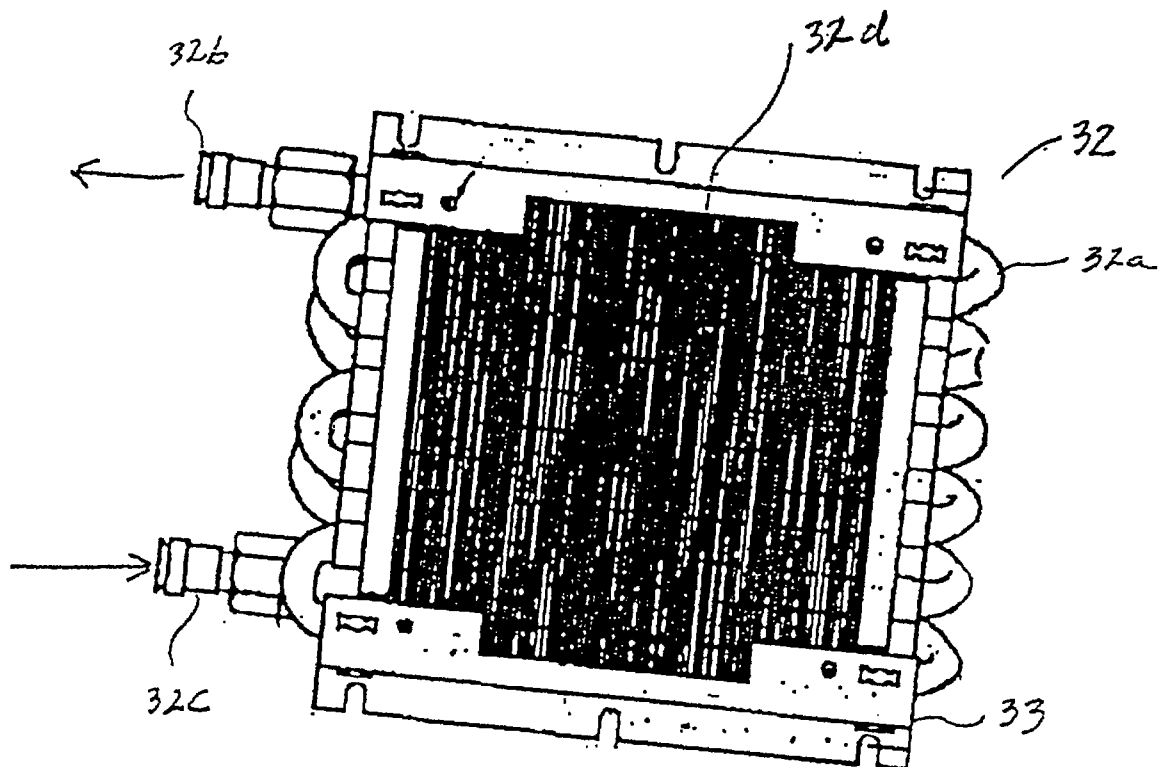


Fig. 3

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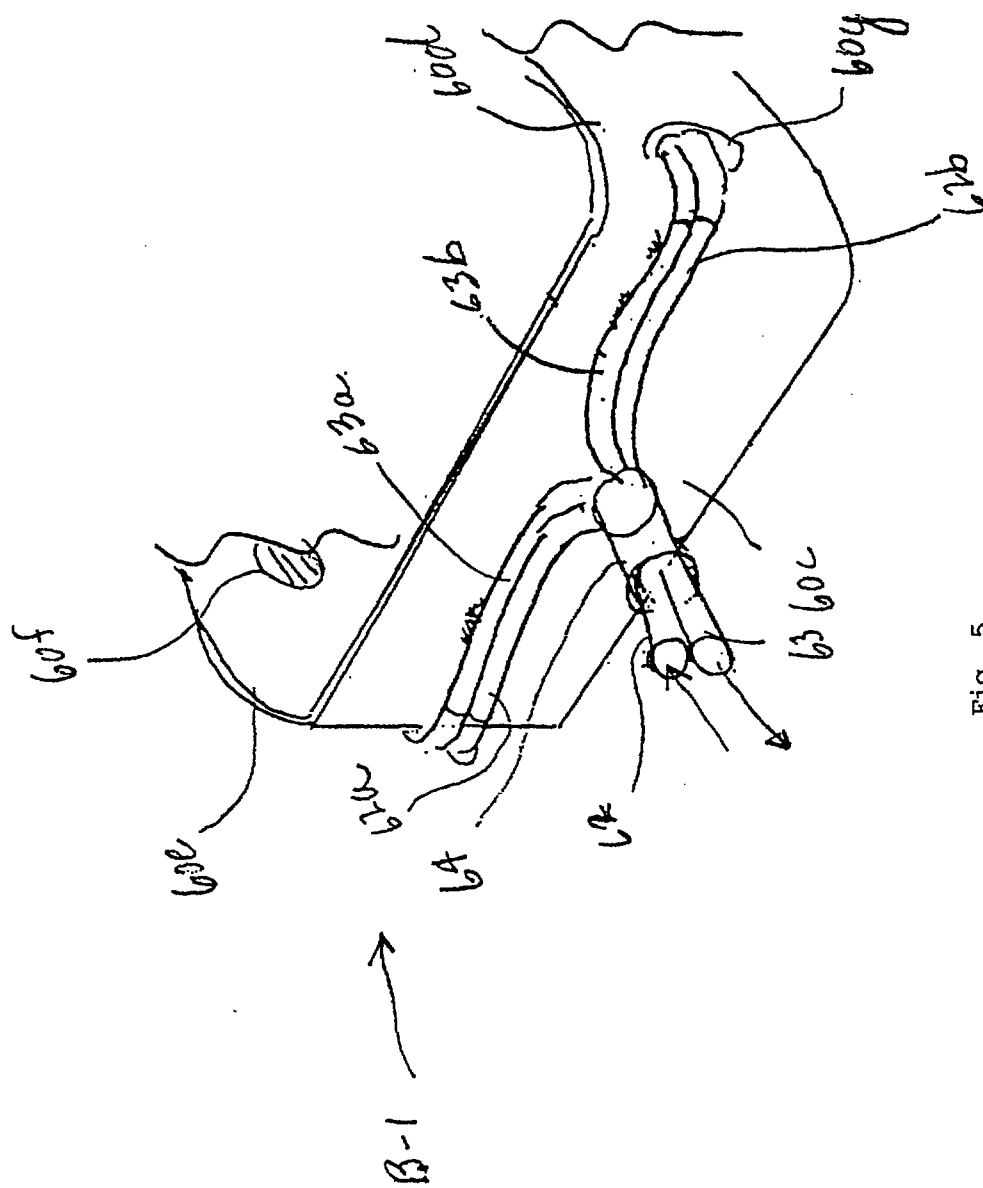


Fig. 5

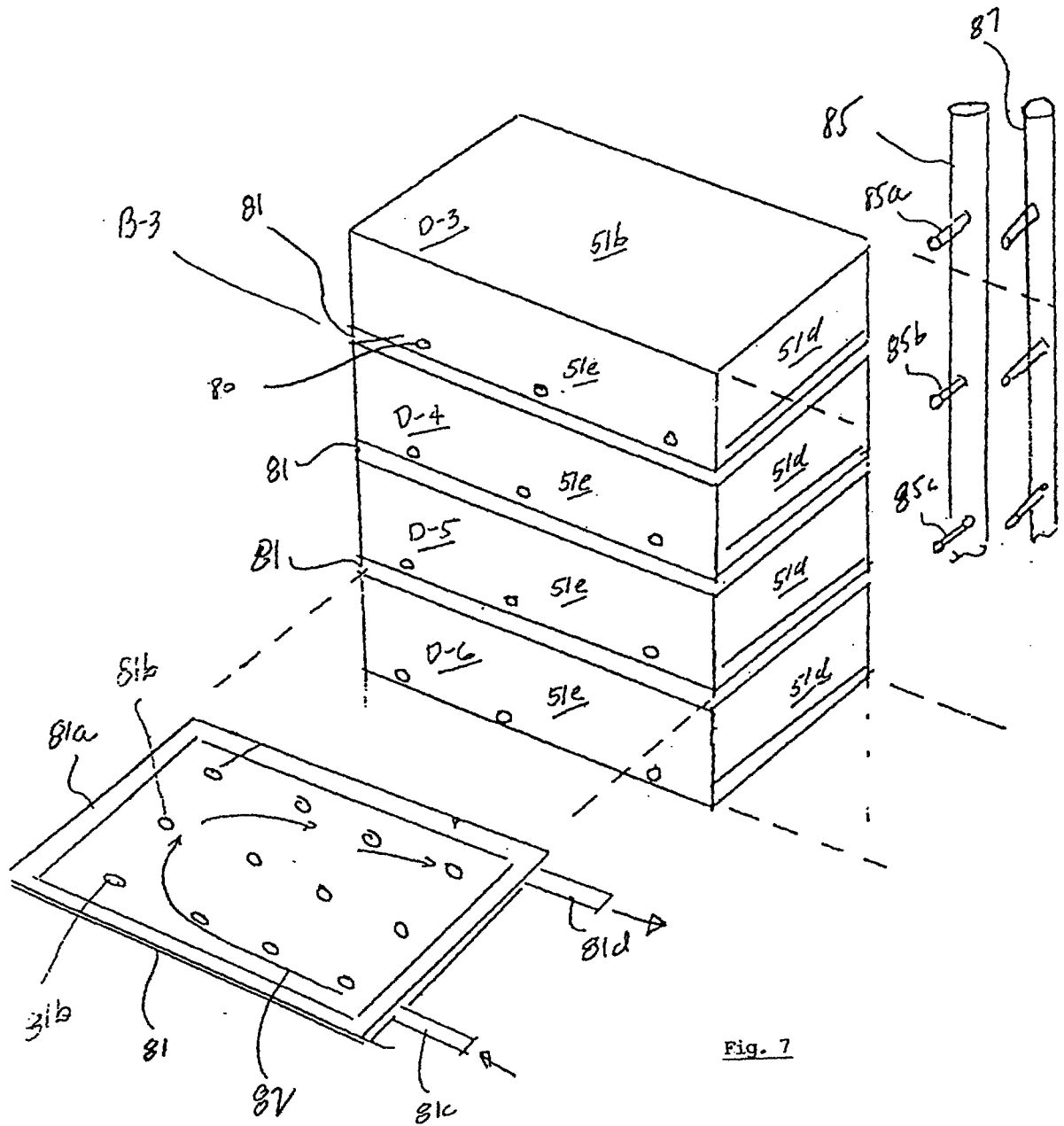
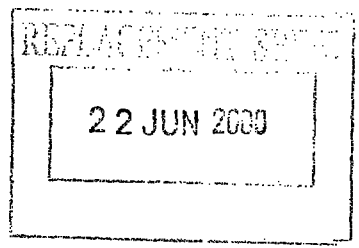


Fig. 7

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Claims:

1. Electronic apparatus comprising:
a generally rectangular chassis (13) having first and second sets of opposing side walls(12a, 12b, 14a, 14b);
5 a plurality of electronic components mounted with said chassis (13), inside said side walls (12a, 12b, 14a, 14b), including a mother board (15);
said mother board (15) having a plurality of extension mounting slots, a processor board (16) mounted in one of said mounting slots and having a high heat generating chip (P) mounted thereon;
10 a power supply (21) mounted on the chassis (13) at the junction of, and having sides respectively adjacent to, one of said first set of side walls (12b) and one of said second set of side walls (14a) of said chassis (13), said power supply (21) having a side-mounted fan (22) adjacent to said power supply (21); and
a heat exchange assembly for dissipating operating heat generated by said high
15 heat generating chip (P) including:
a heat transfer -plate (34) having a configuration substantially identical to the bottom surface of said high heat generating chip (P), said heat transfer plate (34) mounted in thermally conductive relation with the bottom surface of the heat generating chip (P), said heat transfer plate (34) having liquid coolant inlet and exit
20 ports (36, 35), and having a passageway (34a) internally thereof to provide for flow of coolant from said inlet port (36) to said exit port (35);
an air to liquid heat exchanger (32) mounted within said chassis side walls (12a, 12b, 14a, 14b) adjacent to said fan (22), said air to liquid heat exchanger (32) having an inlet port (32) in fluid communication with the exit port (35) of the heat
25 transfer plate (34), and having an exit port (32b) in fluid communication with a plurality of spaced liquid coolant passageways (32a) positioned to receive fan generated air flow in order to reduce the temperature of coolant flowing through said passageways (32a) from said inlet port (32c) to said exit port (32b);
a pump (30) mounted within said chassis side walls (12a, 12b, 14a, 14b), said
30 pump (30) having a low pressure entry port (30a) in fluid communication with the exit



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18

port (32b) of the air to liquid heat exchanger (32), and a high pressure exit port (30b) in communication with the inlet port (36) of the heat transfer plate (34).

2. Electronic apparatus of claim 1, wherein:

5 said pump (30), heat transfer plate (34), tubing and air side heat exchanger (32) provide a dosed system for circulating liquid coolant.

3. Electronic apparatus of claim 2, wherein:

10 said coolant comprises a mixture of approximately 50 per cent water and approximately 50 per cent ethylene glycol.

4. Electronic apparatus of claim 1, wherein:

said fan (22) has a rectangular configuration and said air side heat exchanger (32) has a substantially similar configuration.

15

5. Electronic apparatus of claim 1, wherein:

said electronic chassis (13) produces an air rise in ambient temperature of 10°C when mounted within a housing for a computer, and said high heat generating chip (P) having a design operating temperature in the range 60-70°C, and
20 said air to liquid heat exchanger (32) provides sufficient change in temperature from said inlet port to said exit port to maintain the operating temperature of said high heat generating chip (P) at about 55°C.

6. A computer, comprising:

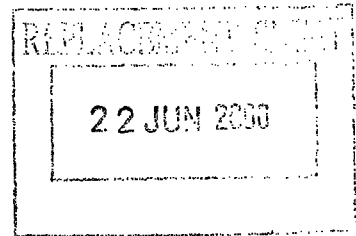
25 a generally box-like rectangular external housing containing an apparatus according to any of claims 1-5, and wherein said fan (22) is a computer system cooling fan.

30



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APPENDED SHEET



7. Electronic apparatus, comprising:

a generally rectangular chassis having first and second sets of opposing side walls;

a plurality of electronic components mounted on said chassis within said side walls, including a hard disk drive (D-1), said hard disk drive having a generally rectangular box-like container (51);

a heat exchange system for said hard disk drive, including:

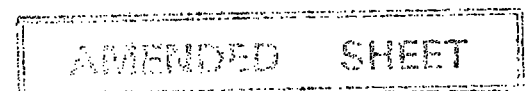
a generally U-shaped heat exchange clip (B-1) including first and second arms (60a, 60b) integrally formed with a base (60c), said U-shaped clip (B-1) receiving, and resiliently engaging with, opposing surfaces (51e, 51f) of said hard disk drive (D-1);

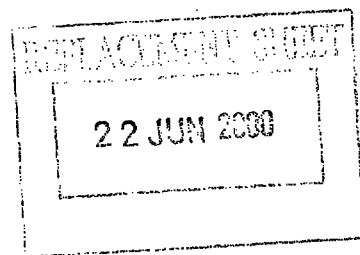
a coolant loop mounted with said U-shaped heat exchange clip, said coolant loop including a first loop section (62a) attached to and extending along said first arm (60a) of said heat exchange clip (B-1) and a second loop section (62b) attached to and extending along said second arm (60b) of said heat exchange clip (B-1) for circulating liquid coolant to absorb heat transferred from said hard disk drive container (51) to said first and second arms (60a, 60b) of said heat exchange clip (B-1);

and a closed circulation system (30, 32) for circulating liquid coolant through said cooling loop (62a, 62b, 63a, 63b) mounted on said U-shaped clip (B-1) and reducing the temperature of said coolant circulating from said cooling loop (62a, 62b, 63a, 63b) before recirculating said coolant to said cooling loop (62a, 62b, 63a, 63b).

8. Electronic apparatus of claim 7, wherein:

said coolant loop first and section sections (62a, 62b, 63a, 63b) are formed of tubing for directing the flow of liquid coolant, said coolant loop including first and second inlet tubing sections (62a, 62b) attached to said base (60c) and to said first and second arms (60a, 60b) of said U-shaped clip (B-1), respectively, and first and second outlet tubing sections (63a, 63b) attached to said base (60c) and to said first and second arms (62a, 62b) of said U-shaped clip (B-1), said inlet and outlet sections being interconnected on each of said arms such that liquid coolant can flow in parallel from said first and second inlet sections (62a, 62b) to said first and second outlet





sections (63a, 63b) in order to absorb heat from said container (51) of said hard disk drive (D-1).

9. Electronic apparatus of claim 7, comprising:

5 each of said first and second arms (60a, 60b) of said U-shaped clip (B-1) has an opening therein (60f, 60g), said first loop section and said second loop section (62a, 62b, 63a, 63b) extending through said openings in said first arm and said second arm (60f, 60g) for attachment to the outside surface of each arm (60a, 60b).

10 10. Electronic apparatus, comprising:

a generally rectangular chassis having first and second sets of opposing side walls;

a plurality of electronic components mounted on said chassis within said side walls, including a hard disk drive (D-2), said hard disk drive having a generally rectangular box-like container (51), having a top surface (51b), bottom surface and two sets of opposing side surfaces (51c, 51d, 51e, 51f); and

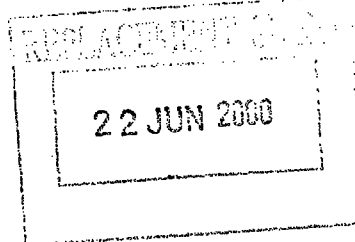
a heat exchange apparatus for controlling the operating temperature of said hard disk drive, including:

20 a rectangular heat transfer plate (70) having substantially the same dimensions as a surface (51b) of said hard disk drive generally rectangular box-like container (51), said heat transfer plate (70) being mounted onto said one of said surfaces (51b) of said hard disk drive generally rectangular box-like container (51);

25 a tubular cooling section (71a, 71b) being mounted on to said heat transfer plate (70) and extending across said plate (70) in a generally rectangular configuration and having an exit section (71b) and an inlet section (71a); and,

coolant circulation means (30) operatively connected to said exit section (71b) and to said inlet section (71a) to reduce the temperature of coolant exiting said exit section (71b) of said cooling tubular section and circulating said coolant at said reduced temperature to said inlet section (71a) of said cooling tubular section.



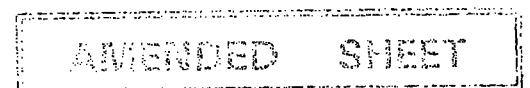


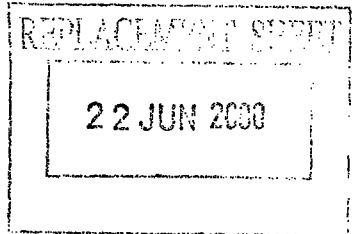
11. Electronic apparatus of claim 10, including resilient clips (72) engaging said inlet section and said exit section and opposing surfaces (51e, 51f) of said hard disk drive (D-2).

- 5 12. Electronic apparatus, comprising:
 a generally rectangular chassis for mounting electronic components;
 a plurality of hard disk drive units (D-3 - D-6) mounted in a vertical array, each
of said hard disk drive units having a generally rectangular box-like housing (51)
including a rectangular top surface (51b) and a rectangular bottom surface;
10 a heat dissipation assembly for said vertical array of hard disk drive units,
including:
 heat transfer panels (81) mounted between said bottom surface and said top
surface (51b) of adjacent hard disk drive housings (51), each said heat transfer panel
(81) having a liquid coolant circulation path (82) for circulating liquid coolant to
15 absorb heat generated during operation of said hard disk drive units (D3 - D-6); and
 a coolant circulation assembly operable to continuously remove from said
panels, coolant which has been heated by said hard disk drive units (D-3 - D-6) and
for reducing the temperature of said heated coolant and returning said coolant to said
panels (82) in order to dissipate heat generated by said hard disk drive units (D-3 - D-
20 6).

13. Electronic apparatus of claim 12, wherein: each said heat transfer panel (81) is flexible.

- 25 14. Electronic apparatus of claim 12, wherein
 each said heat transfer panel (81) is hollow and is formed from at least two
sheets of flexible material arranged in a mutually parallel, facing relationship.





15. Electronic apparatus of claim 14, wherein:
each said hollow heat transfer panel has an inlet opening (81c) and an outlet opening (81d); and

5 said coolant circulation assembly includes a pump (30) communicating with each said inlet opening (81c), and an air side heat exchanger (32) communicating with each said outlet opening (81d).

16. Electronic apparatus of claim 12, wherein:
said coolant is a mixture of water and ethylene glycol.

10

17. Electronic apparatus of claim 16, wherein:
said liquid is a mixture of about fifty percent by volume of water, and about fifty percent by volume of ethylene glycol.

15

18. Electronic apparatus according to claim 12, wherein:
each said heat exchange panel is formed of opposing flexible sheets of material; and
each said heat transfer panel has a peripheral sealed edge (81a) forming a hollow cavity therein to receive said coolant.

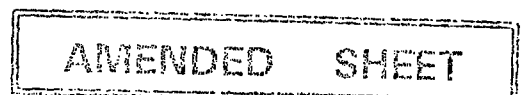
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19. Electronic apparatus according to claim 18, including:
a plurality of interbonded points within said hollow cavity wherein said opposing flexible sheets are joined together.

25

20. Electronic apparatus according to claim 15, wherein:
said heat dissipation assembly includes two or more of said heat transfer panels (81);

an inlet flow manifold (87) in fluid communication with inlet openings (81c) of said two or more heat transfer panels (81) and an outlet flow manifold (85) in fluid



communication with each of said outlet openings (85) of said two or more heat transfer panels (81); and

said inlet and outlet flow manifolds (87,85) being in fluid communication with said coolant circulation assembly.

5

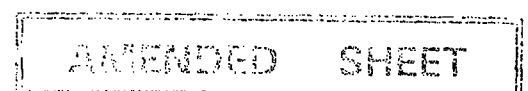
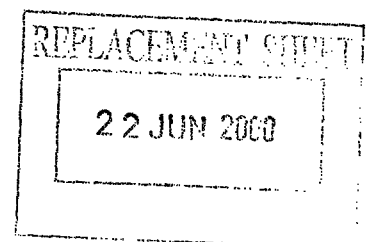
21. Electronic apparatus according to claim 13, wherein:

each said heat transfer panel (81) is expandable during flow of liquid coolant therethrough to enhance heat transfer, and is contractable to allow for greater ease in removal of said disk drive units (D-3 - D-6).

10

22. Electronic apparatus according to claim 14, wherein each said heat transfer panel (81) comprises layers of polyamide film separated by fluorcarbon film.

23. Electronic apparatus according to claim 22, wherein heat transfer from
15 said disk drive housings (51) expands said heat transfer panels thereby enhancing heat transfer from said disk drive housings (51).



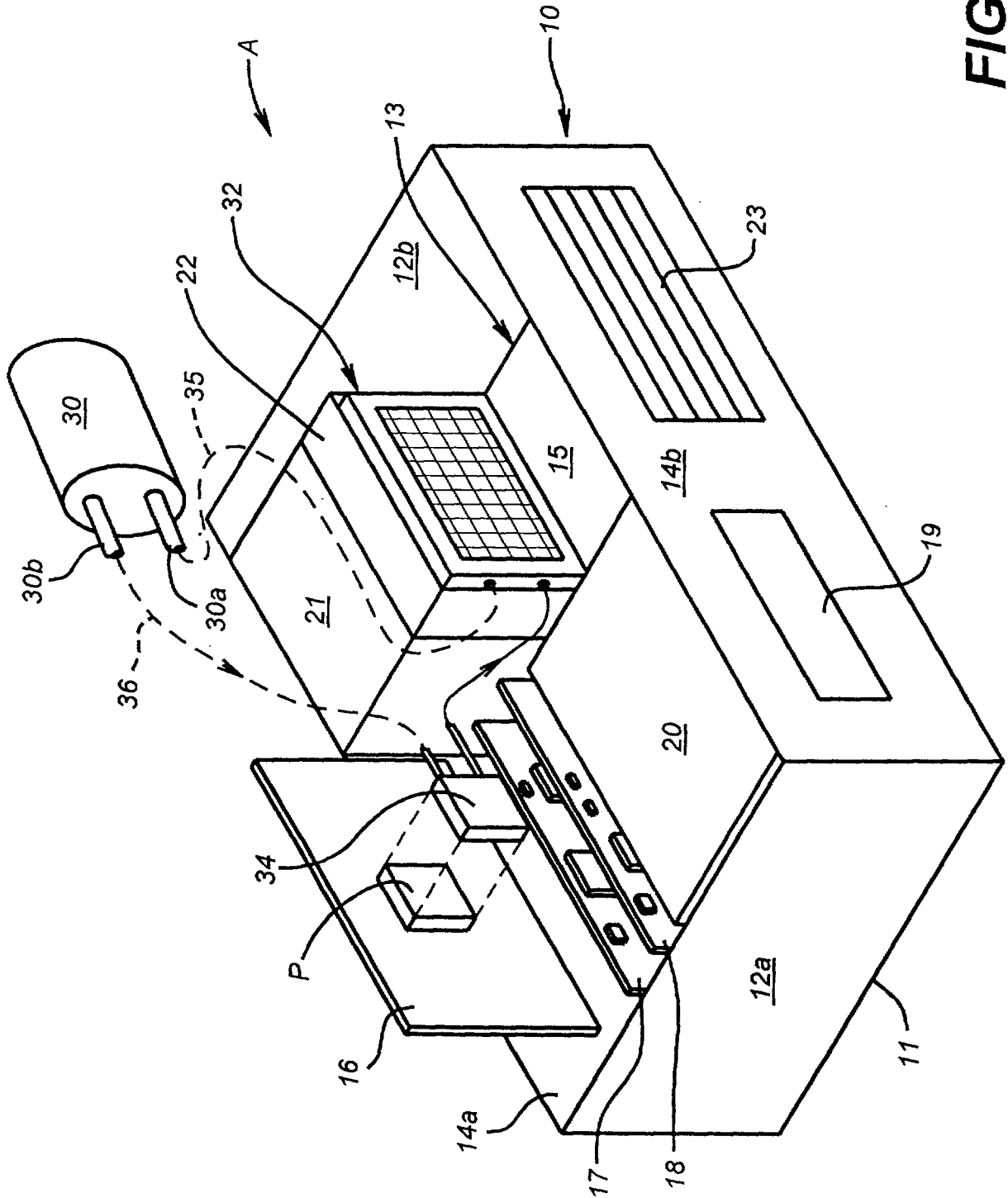
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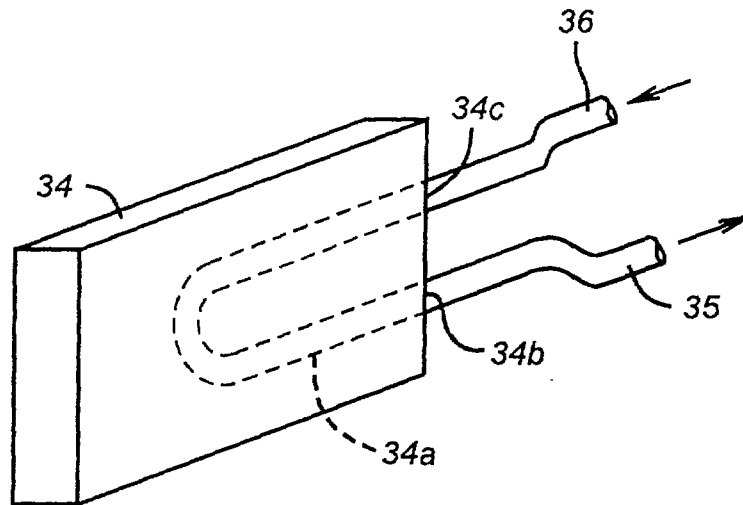
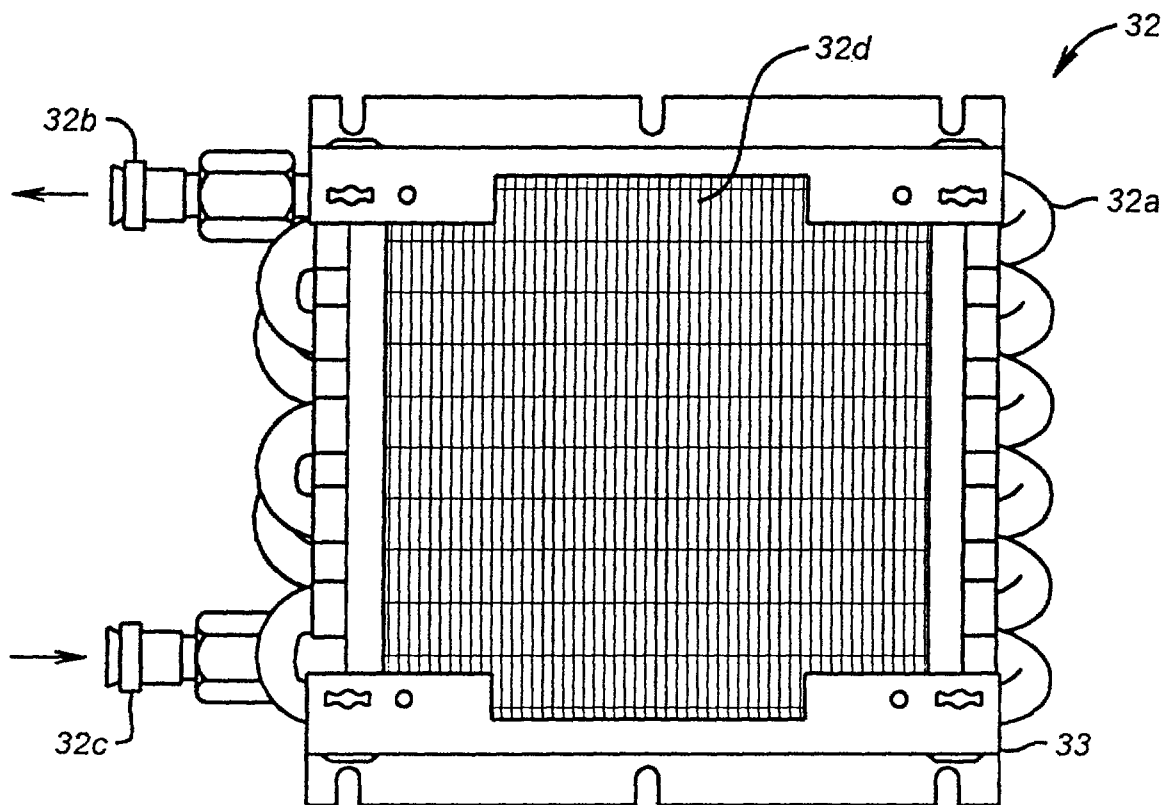
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FIG. 1



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**FIG. 2****FIG. 3**

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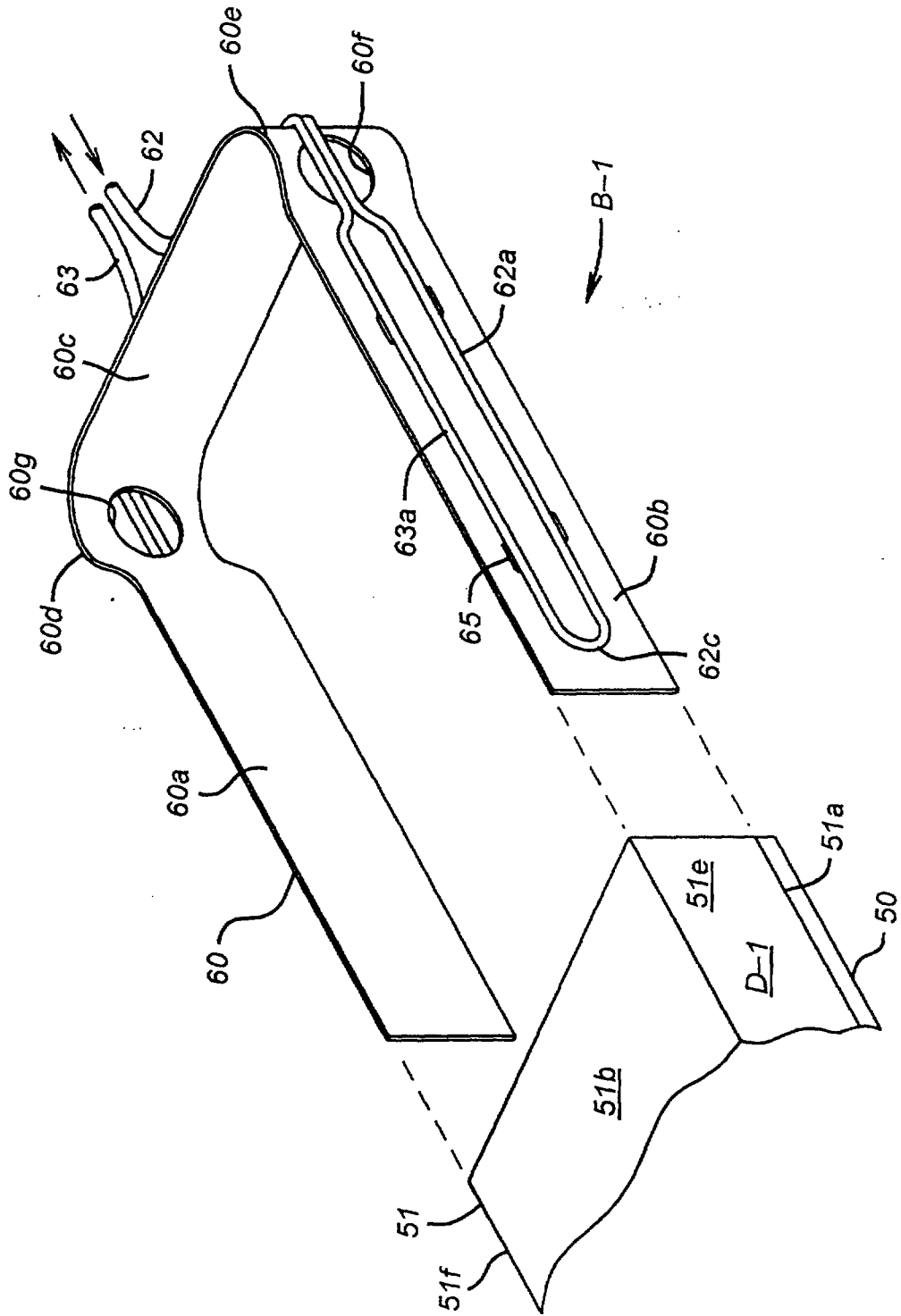
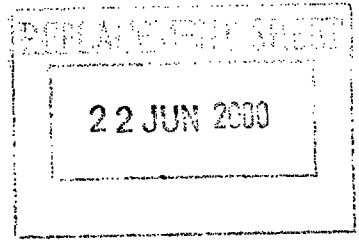


FIG. 4

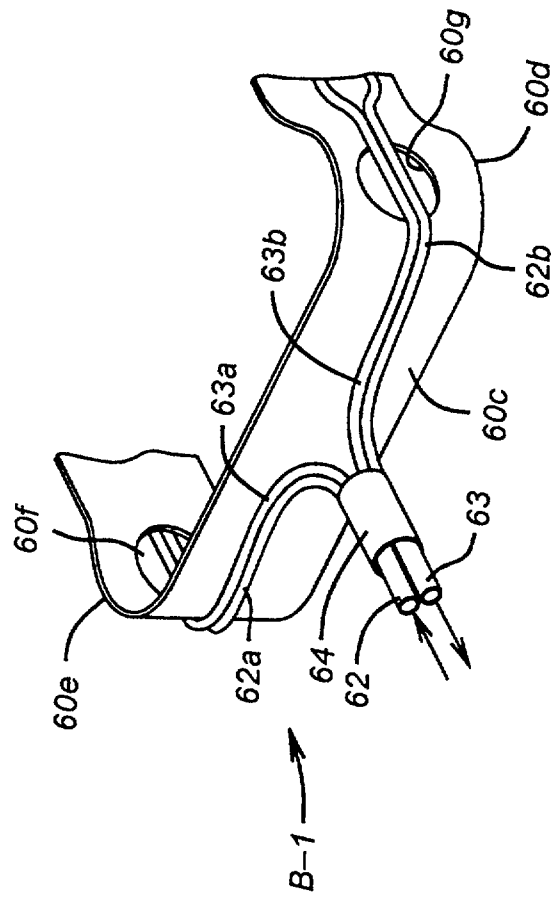
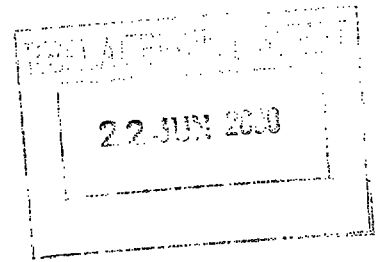


FIG. 5

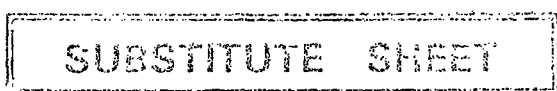


FIG. 6

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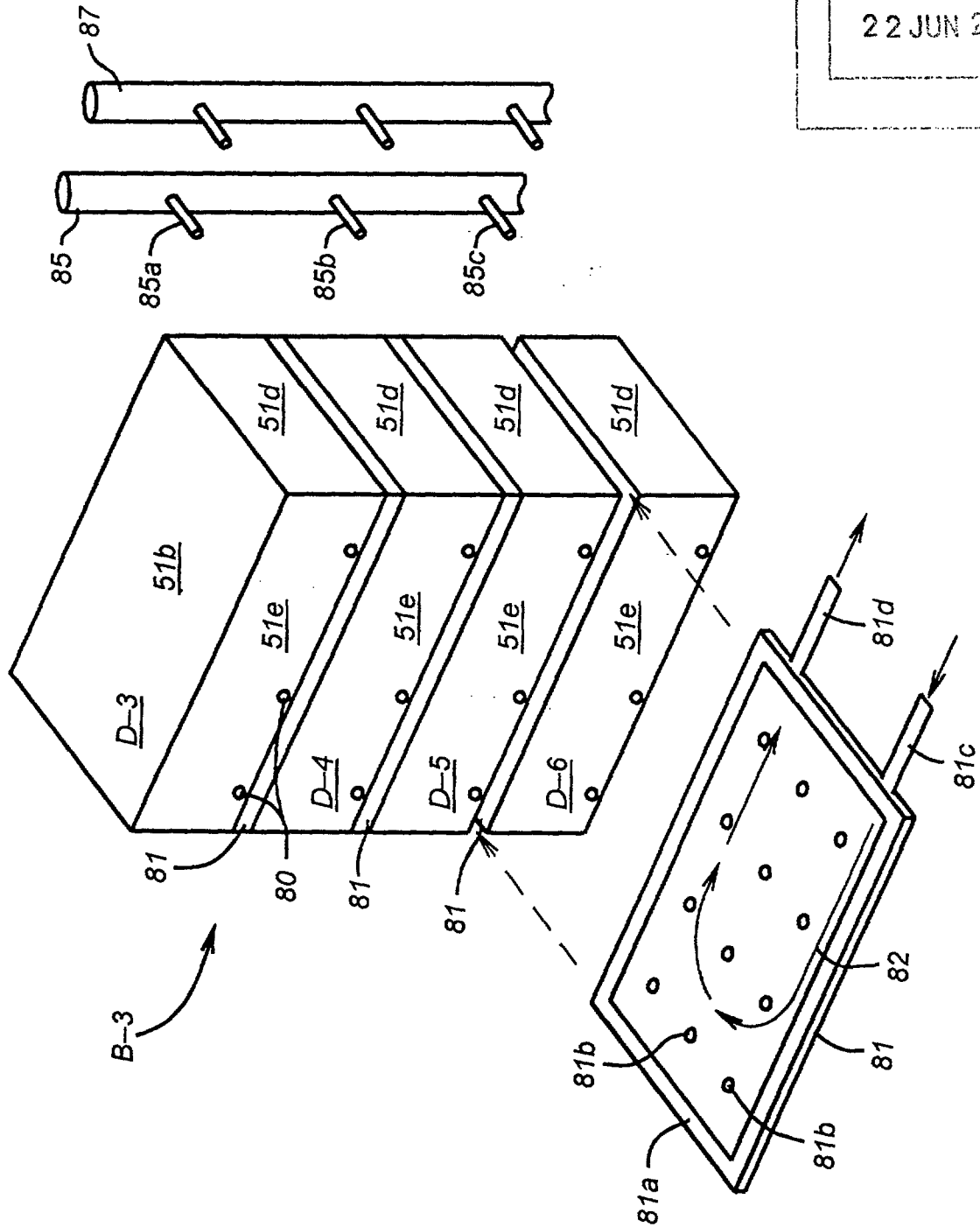


FIG. 7

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