

FORCED AIR COOLING APPARATUS AND METHOD

FIELD OF THE INVENTION

5 The present invention relates to a forced air cooling apparatus. More particularly, the present invention relates to a forced air cooling apparatus for cooling heat generating devices, such as electronic devices mounted in electronic racks. The present invention also relates to a method of cooling heat generating devices using a forced air cooling apparatus.

10 BACKGROUND

Electronic devices are designed to operate within certain temperature ranges. When in operation, these devices will generate heat. The heat, when not dissipated adequately, may result in the electronic devices operating outside their designed temperature ranges. Frequent operation at increased temperatures may cause the
15 electronic devices to fail prematurely.

In a military aircraft, electronic devices, such as avionics equipment and electronic card cages, are mounted in electronic racks. Forced air cooling is normally employed to dissipate heat that is generated by these electronic devices. The electronic racks are linked to a cold air distribution network which channels a pre-
20 determined flow rate of cold air into each of the electronic racks to cool the electronic devices stored therein.

In an avionics upgrade program, certain electronic racks are made redundant and are replaced by new ones. The new electronic racks may dissipate a higher amount of heat than the electronic racks that were made redundant, thereby raising a
25 potential problem of inadequate cooling should the flow rate of cold air into the new electronic racks remains unchanged. Therefore, in order to effectively cool the new racks, air flow rate parameters in the entire cold air distribution network may have to be re-programmed to cater to the higher heat dissipation of the new electronic racks. Such a process can be complex, and may not be worth the effort if the upgrade program only
30 involves replacing one or two electronic racks. Further, more often than not, the pre-determined flow rate of cold air into each of the electronic racks is provided in surplus

since there are no means of distributing the cold air to each of the electronic card cages in accordance with the amount of heat each of them dissipates. It will thus be desirable if only a localised modification needs to be carried out in the new racks without having to disturb the parameters of the entire cold air distribution network. A new cooling rack
5 having means of optimising the available pre-determined flow rate of cold air so as to sufficiently cool the electronic card cages stored therein will therefore be desirable.

US Patent No. 6,305,180 granted on 23 October 2001 to Miller et al. relates to a cooling system for cooling electronic devices mounted in electronic racks. The system uses a chiller unit between adjacent racks to cool air that is heated from a previous rack
10 before it flows into an adjacent rack.

US Patent No. 6,574,104 granted on 3 June 2003 to Patel et al. discloses a cooling system configured to adjust cooling fluid flow to various racks located throughout a data centre based on detected or anticipated temperatures at various locations throughout the data centre.

15 An alternative cooling system that is more cost effective, simple and yet versatile could usefully be provided.

SUMMARY OF INVENTION

20 The present invention relates to a forced air cooling apparatus for use in cooling heat generating devices, in particular electronic card cages and avionics equipment in a military aircraft. The apparatus comprises a casing that is in fluid communication with a cold air source, the casing having an inlet port for receiving the cold air, a forced air cooling module for distributing the cold air to the heat generating devices, and an outlet
25 port for exiting cold air that has been heated by the heat generating devices. The forced air cooling module comprises a primary duct having a fan installed therein, a plurality of secondary ducts affixed orthogonally to the primary duct, and a plurality of spray bars mounted along each secondary duct. Orifice plates are positioned within the inlet ports and below each junction where the secondary duct intersects the primary
30 duct, to direct adequate amounts of cold air to the heat generating devices. The present invention further provides means of reducing electromagnetic interference in

the casing, for instance, by installing EMI filters within the outlet port and downstream of the orifice plate in the inlet port.

In an aspect of the present invention, there is provided a forced air cooling apparatus in fluid communication with a cold air source, said apparatus comprising a casing having

an inlet port for receiving cold air into the casing, the inlet port having means for channelling a first pre-determined flow rate of cold air into the casing;

a forced air cooling module comprising a primary duct, a plurality of secondary ducts mounted orthogonally to the primary duct, and a plurality of spray bars mounted along each secondary duct to exit the cold air onto the heat generating devices, the secondary ducts having means for channelling a second pre-determined flow rate of cold air from the primary duct, through the secondary duct, to the spray bars; and

an outlet port for exiting the cold air that is heated by the heat generating devices.

The forced air cooling apparatus further comprises means for reducing electromagnetic interference in the casing.

In another aspect of the present invention, there is provided a method of forced air cooling heat generating devices mounted within a casing, the heat generating devices arranged vertically one above the other with the bottom most being a first device, comprising

drawing in a pre-determined flow rate of cold air into the casing, the pre-determined flow rate of cold air having a first portion and a second portion;

directing the second portion of the cold air to the first device; and

distributing the first portion of the cold air to each of the heat generating devices above the first device in accordance with heat dissipation requirements of the heat generating devices above the first device.

The method further comprises means for reducing electromagnetic interference in the casing.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features of the present invention will readily be apparent from the following detailed description of a non-limiting examples, with reference to the accompanying drawings, in which:

5 **Figure 1a** is a perspective view of a forced air cooling apparatus in a simplified configuration, showing an inlet port, forced air cooling module and outlet port, in accordance with a first embodiment of the present invention;

Figure 1b shows a perspective view of a forced air cooling apparatus in a simplified configuration with electronic card cages (shown in bold lines) mounted therein, in accordance with a first embodiment of the present invention;

10 **Figure 2a** shows a perspective view of a forced air cooling apparatus in a simplified configuration showing a possible mounting means for mounting the electronic card cages;

Figure 2b shows a perspective view of an electronic card cage;

15 **Figure 3** is a perspective view of the forced air cooling apparatus in a simplified configuration in accordance with a second embodiment of the present invention;

Figure 4 is a perspective view of a forced air cooling system comprising two forced air cooling apparatus arranged in parallel, in preferred configurations, in accordance with the embodiments of the present invention;

20 **Figure 5a** is a perspective view of a forced air cooling apparatus in accordance with a third embodiment of the present invention.

Figure 5b is a rear perspective view of an electronic card cage to be mounted onto the forced air cooling apparatus in accordance with a third embodiment of the present invention.

25

DETAILED DESCRIPTION

Figure 1 shows a simplified configuration of a forced air cooling apparatus 10 for cooling heat generating devices in accordance with a first embodiment of the present invention. The heat generating device can be, for example, an electronic card cage 20 in which electronic cards 28 are slotted therein, as shown in Figure 2b. The electronic

30

card cages are arranged one on top of the other as shown in Figure 1b, wherein the electronic card cage at the bottom is a first electronic card cage 22, the middle electronic card cage is a second electronic card cage 24, and the top electronic card cage is a third electronic card cage 26. As best seen in Figure 1a, the forced air cooling apparatus 10 comprises a casing 100 having an inlet port 200, a forced air cooling module 300, and an outlet port 400. The casing 100 has a first side wall 110 (being the left end of the casing 100), a second side wall 120 (being the right end of the casing 100), a third side wall 130 (being the front end of the casing 100), a fourth side wall 140 (being the rear end of the casing 100), a bottom wall 150 and a top wall 160.

The inlet port 200 is positioned at the bottom wall 150 of the casing 100, where it links the casing 100 to a cold air source 30. Cold air enters the casing 100 via the inlet port 200. The cold air source 30 is preferably a cold air duct 32 carrying conditioned air originating from a refrigeration package (not shown). The inlet port 200 could, for example, be a piping that runs from the casing 100 to the cold air duct 32. An inlet orifice plate 220 is positioned inside the inlet port 200.

The forced air cooling module 300, which may be mounted onto a corner where the fourth side wall 140 and the first side wall 110 intersects, comprises a primary duct 320, and a plurality of secondary ducts, i.e., a first secondary duct 340 and a second secondary duct 360, mounted orthogonally onto the primary duct 320. Each of the first secondary duct 340 and the second secondary duct 360 has a plurality of spray bars 380 mounted along its length. A suction fan 322 is installed within the primary duct 320, preferably at the bottom portion. Primary duct orifice plates are installed within the primary duct 320 below each junction where the secondary duct intersects the primary duct 320. For instance, a first primary duct orifice plate 324 is attached below a first junction where the first secondary duct 340 intersects the primary duct 320. A second secondary duct orifice plate 326 is attached below a second junction where the second secondary duct 360 intersects the primary duct 320.

Figure 2a shows a possible mounting means for mounting the electronic card cages within the forced air cooling apparatus 10. A pair of support frames 500, 510 may be mounted onto a pair of opposing side walls, for instance, onto the first side wall 110 and the second side wall 120. Each support frame 500, 510 has a recess portion

520 and two projecting portions 540 and 560, wherein the recess portion 520 is between the projecting portions 540 and 560. The electronic card cage 20, as shown in Figure 2b, may have a protruding portion 21 on its opposing sides, wherein width of the protruding portion 21 is the width of the recess portion 520 of the support frames 500, 510. The electronic card cage 20 holds a plurality of electronic cards 28.

When slotted into the support frames 500, 510, the protruding portion 21 of the electronic card cage 22, 24 or 26 fits into the recess portion 520 of the support frames 500, 510. The first secondary duct 340 is in line with the base of the second electronic card cage 24, and the second secondary duct 360 is in line with the third electronic card cage 26. The spray bars 380 along the length of the first secondary duct 340 are positioned beneath the base of the second electronic card cage 24, and the spray bars 380 along the length of the second secondary duct 360 are positioned beneath the base of the third electronic card cage 26.

A perforated plate 600 having the same cross sectional area as the casing 100 is positioned between the forced air cooling module 300 and the inlet port 200. The volume of space between the inlet port 200 and the perforated plate 600 defines an air plenum 40. The perforated plate 600 has a first hole 620 and a second hole 640 cut into it. The first hole 620 is directly below the primary duct 320 of the forced air cooling module 300, and the second hole 640 is directly below the first electronic card cage 22.

The outlet port 400 is positioned at the top wall of the casing to allow air that has been heated by the electronic card cages 22,24,26 to exit. The outlet port 400 could, for example, be a pipe (not shown) linking the casing 100 to the refrigeration package such that air that is heated by the electronic card cages 22,24,26 can be cooled and recycled for further use.

In accordance with a second embodiment of the present invention as shown in Figure 3, there is provided a forced air cooling apparatus 10 of the first embodiment, further comprising means for reducing electromagnetic interference in the casing 100. This may be achieved with the use of EMI filters 700 positioned within the outlet port 400 and inlet port 200. The EMI filter 700 is preferably of type TECKCELL-A Honeycomb, size 0.318 cm (0.125 inches) wide and 1.27 cm (0.5 inches) deep. The EMI filter 700 may be tin plated to improve shielding.

In conventional forced air cooling systems, a plurality of electronic racks housing electronic devices, such as electronic card cages, are linked to a cold air distribution network which channels a pre-determined flow rate of cold air into each of the electronic racks. Should an electronic rack be replaced, or the equipment in the electronic rack be replaced, the resulting new rack may have a higher heat dissipation value than the previous rack. Consequently, the pre-determined flow rate of cold air may not be sufficient to cool the new electronic rack. A solution could be to re-program the cold air distribution network to alter the flow rate of cold air into the new rack and other racks in the forced air cooling system. However, such a process may be complex and time consuming. It is also found that these electronic racks do not fully utilise the pre-determined flow rate of cold air as there is no mechanism to channel just enough cold air to each of the electronic devices stored in the rack. Consequently, more cold air than is actually required is utilised.

The present invention, in accordance with the embodiments, functions as an electronic rack. The inlet orifice plate 220 (positioned inside the inlet port 200), and the primary duct orifice plates 324,326 (positioned below each of the junctions where the secondary ducts 340,360 intersect the primary duct 320), permit the desired amount of cold air flow into the electronic card cages 22,24,26 stored in the casing 100.

Cold air from the cold air duct 32 enters the air plenum 40 via the inlet port 200. The inlet orifice plate 220 has an aperture which allows a sufficient flow rate of cold air that is required to cool the electronic card cages 22,24,26 in the casing 100 to pass through. The remaining cold air then travels along the cold air duct 32 to the next forced air cooling apparatus adjacent to the present forced air cooling apparatus 10.

The first and second holes 620,640 in the perforated plate 600 are sized in a manner such that only correct amounts of cold air flow is provided to the primary duct 320 and the first electronic card cage 22. The second hole 640 directly below the first electronic card cage 22 is of a size that allows just enough flow rate of cold air to cool the first electronic card cage 22. The first hole 620 directly below the primary duct 320 allows the remaining cold air in the air plenum 40 up the primary duct 320 with the help of the suction fan 322. Cold air that passes through the second hole 640 in the

perforated plate 600 rises through the first electronic card cage 22 to cool it, and gets partially heated as a result.

The partially heated cold air then rises to the base of the second electronic card cage 24 where it is mixed with fresh cold air from the primary duct 320. The first
5 primary duct orifice plate 324, below at the first junction where the first secondary duct 340 intersects the primary duct 320, has an aperture that allows only enough cold air from the primary duct 320 to travel through the first secondary duct 340 and exiting through the spray bars 380, to mix with the partially heated cold air such that the resulting first mixed cold air can adequately cool the second electronic card cage 24.

10 Similarly, the resulting first mixed cold air then rises through the second electronic card cage 24 and gets partially heated. At the base of the third electronic card cage 26, the partially heated first mixed cold air is mixed with further amounts of fresh cold air. The second secondary duct orifice plate 326 below the second junction
15 where the second secondary duct 360 intersects the primary duct 320 has an aperture that allows only enough cold air from the primary duct 320 to travel through the second secondary duct 360 and exiting through the spray bars 380, to mix with the partially heated first mixed cold air such that the resulting second mixed cold air can adequately cool the third electronic card cage 24. The second mixed cold air that is heated by the third electronic card cage 26 then exit the casing 100 via outlet port 400.

20 A plurality of the forced air cooling apparatus of the present invention can also be connected in parallel to a cold air distribution network in order to form a forced air cooling system. Each apparatus optimises usage of available cold air with the use of orifice plates which direct the cold air into each of the electronic card cages in an amount that is pre-determined in accordance to the heat dissipation of the individual
25 electronic card cages.

Should any of the electronic card cages be replaced, the orifice plates in the secondary ducts and the inlet ports can be changed to alter the flow rate of cold air to cater to the new heat dissipation requirements of the new electronic card cages. In a scenario where an entire apparatus is replaced, the desired distribution of cold air within
30 the new apparatus can be achieved with the use of suitable orifice plates in the primary duct and inlet port. Thus, rather than re-programming the cold air distribution network

to cater to the new heat dissipating requirements, manipulation of the orifice plates can be employed to achieve the same.

Figure 4 shows a preferred configuration of a forced air cooling system 50 comprising two forced air cooling apparatus in accordance with the embodiments of the present invention. The preferred configuration comprises a left casing 800 and a right casing 900, the left casing 800 and the right casing 900 being connected in parallel to a main cold air duct 32.

The right casing 900 has a first inlet port 910, a second inlet port 920, a first forced air cooling module 930, and a first outlet port 940. The first inlet port 910 and the second inlet port 920 are positioned at the base of the right casing 900 linking the right casing 900 to the main cold air duct 32. The first forced air cooling module 930, mounted onto a rear wall 902, comprises a first primary duct 932 with a first secondary duct 934 mounted orthogonally to the first primary duct 932. A plurality of spray bars 936 are mounted along the first secondary duct 934. A first inlet orifice plate 912 is positioned inside the first inlet port 910, and a second inlet orifice plate 922 is positioned inside the second inlet port 920. A first suction fan 938 is installed within the first primary duct 932 at the bottom portion. A first primary duct orifice plate 935 is attached within the first primary duct 932 below the junction where the first secondary duct 934 intersects the first primary duct 932. A first perforated plate 950 is positioned between the first forced air cooling module 930 and the first and second inlet ports 910, 920. The first perforated plate 950 has a first hole 952 cut into it. The first outlet port 940 is positioned at the top of the right casing 900 to allow air that has been heated by the electronic card cages stored therein to exit.

The right casing 900 has support frames (not shown), for instance like those described in Figure 2a, for mounting a first electronic card cage (not shown) and a second electronic card cage (not shown). The first electronic card cage is positioned below the second electronic card cage and each electronic card cage may have protruding portions 21 as illustrated in Figure 2b for mounting purposes. When slotted into the support frames, the first secondary duct 934 is in line with the base of the second electronic card cage. The plurality of spray bars 936 mounted along the length

of the first secondary duct 934 is positioned beneath the base of the second electronic card cage.

5 A storage base compartment base plate 960, having air holes 961, as shown in Figure 4, is positioned above the first forced air cooling module 930 but below the first outlet port 940. Space between the storage compartment base plate 960 and the first outlet port 940 defines a storage space for avionics equipment to be stored therein.

10 EMI filters 937 are positioned inside the first inlet port 910, downstream of the first inlet orifice plate 912, and inside the second inlet port 920, downstream of the second inlet orifice plate 922. The air holes 961 in the storage base compartment plates are also covered with EMI filters 937 for reducing electromagnetic interference.

15 The left casing 800 is similar to the force air cooling apparatus as shown in Figure 3. The difference being that instead of having one inlet port at the bottom wall 150, there are 2 inlet ports, i.e., a third inlet port 810 and a fourth inlet port 820. A third inlet orifice plate 812 is positioned within the third inlet port 810 and a fourth inlet orifice plate 822 is positioned within the fourth inlet port 820. Also, EMI filters 700 are positioned inside the third inlet port 810, downstream of the first inlet orifice plate 812, and inside the fourth inlet port 820, downstream of the second inlet orifice plate 822.

20 In a third embodiment of the present invention, there is provided a forced air cooling apparatus as shown in Figure 5a. The forced air cooling apparatus comprises the casing 100, inlet port 200, outlet port 400, perforated plate 600, EMI filters 700 and inlet orifice plate 220 in accordance with the first and second embodiments of the present invention. A forced air cooling module 300 is mounted onto a corner where the fourth side wall 140 and the first side wall 110 intersect. The module comprises a primary duct 320, and a plurality of secondary ducts, i.e., a first secondary duct 340 and a second secondary duct 360, mounted orthogonally onto the primary duct 320. Each of the first secondary duct 340 and the second secondary duct 360 has a plurality of air vents 390 along its length. A suction fan 322 is installed within the primary duct 320, preferably at the bottom portion. Primary duct orifice plates are installed within the primary duct 320 below each junction where the secondary duct intersects the primary duct 320. For instance, a first primary duct orifice plate 324 is attached below a first junction where the first secondary duct 340 intersects the primary duct 320. A second

25

30

secondary duct orifice plate 326 is attached below a second junction where the second secondary duct 360 intersects the primary duct 320.

Figure 5b shows a rear perspective view of an electronic card cage 20 to be mounted onto the forced air cooling apparatus in accordance with the third embodiment of the present invention. The electronic card cage 20 has a plurality of spray bars 380 attached at its base. When mounted within the casing 100, the spray bars are joined to the air vents 390. The spray bars 380 may be positioned at areas of the electronic card cage holding electronic cards that dissipate more heat than the others. In particular, in areas of the electronic card cage where the electronic cards dissipate a high amount of heat, the spray bar positioned therein can be fabricated with the exit directed towards the electronic cards such that cold air is channelled directly onto the electronic cards without having to mix with the partially heated cold air from the previous electronic card cage.

It is understood by those skilled in the art that even though numerous characteristics and advantages of the embodiments of the present invention have been set forth in the foregoing description, this disclosure is illustrative only. Other modifications may be made, especially in matters of structure, arrangement of parts and/or steps within the principles of the invention to the full extent indicated by the broad general meaning of the appended claims without departing from the scope of the invention.

25

30

CLAIMS

1. A forced air cooling apparatus adapted for fluid communication with a cold air source, said apparatus comprising a casing having:
 - 5 an inlet port for receiving cold air into the casing, the inlet port having means for channelling a first pre-determined flow rate of cold air into the casing;
a forced air cooling module comprising a primary duct, a plurality of secondary ducts mounted orthogonally to the primary duct, and a plurality of spray bars mounted along each secondary duct to exit the cold air onto the heat generating devices, the
10 secondary ducts having means for channelling a second pre-determined flow rate of cold air from the primary duct, through the secondary duct, to the spray bars; and
an outlet port for exiting the cold air that is heated by the heat generating devices.
- 15 2. The forced air cooling apparatus according to claim 1, further comprising means for reducing electromagnetic interference in the casing.
3. The forced air cooling apparatus according to claim 1 or 2, wherein the means for providing a first pre-determined flow rate of cold air into the casing is an inlet orifice
20 plate, having an aperture sized for the purpose, positioned within the inlet port.
4. The forced air cooling apparatus according to claim 1, 2 or 3, wherein the primary duct comprises a suction fan installed therein.
- 25 5. The forced air cooling apparatus according to any one of the preceding claims, wherein the means for channelling a second pre-determined flow rate of cold air from the primary duct, through the secondary duct, to the spray bars is a primary duct orifice plate sized for the purpose, positioned within the primary duct below a junction where the secondary duct intersects the primary duct.

6. The forced air cooling apparatus according to any one of the preceding claims, wherein the first pre-determined flow rate of cold air is the flow rate of cold air that is required to cool all the heat generating devices stored in the casing.
- 5 7. The forced air cooling apparatus according to any one of the preceding claims, wherein second pre-determined flow rate of cold air is the flow rate that is required to cool the heat generating device that is in proximity to the secondary duct.
8. The forced air cooling apparatus according to any one of the preceding claims,
10 further comprising a perforated plate positioned between the inlet port and the forced air cooling module, the perforated plate having a first hole and a second hole cut into it.
9. The forced air cooling apparatus according to claim 2, wherein the means for reducing electromagnetic interference is an EMI filter installed within the outlet port and
15 the inlet port.
10. The forced air cooling apparatus according to claim 9, wherein the second hole is of a size that allows a flow rate of cold air, that is required to cool the heat generating device directly above the perforated plate, to pass through.
20
11. A method of forced air cooling of heat generating devices mounted within a casing, the heat generating devices arranged vertically one above the other with the bottom most being a first device, the method comprising the following steps:
drawing in a pre-determined flow rate of cold air into the casing, the pre-
25 determined flow rate of cold air having a first portion and a second portion;
directing the second portion of the cold air to the first device; and
distributing the first portion of the cold air to each of the heat generating devices above the first device in accordance with heat dissipation requirements of the heat
generating devices above the first device.
- 30

12. The method according to claim 11, further comprising reducing electromagnetic interference in the casing.

5 13. The method according to claim 11 or 12, wherein the pre-determined flow rate of cold air into the casing is the flow rate that is required to cool all the heat generating devices in the casing.

10 14. The method according to claim 11, 12 or 13, wherein the second portion of the cold air is the flow rate of cold air that is required to cool the first device.

15 15. The method according to any one of claims 11-14, wherein directing the second portion of the cold air to the first device is carried out by means of a perforated plate, positioned below the first device, having a hole that allows only the second portion of the cold air to pass through.

16. The method according to any one of claim 11 to 15, wherein distributing the first portion of the cold air to each of the heat generating devices above the first device is carried out using orifice plates of suitable apertures.

20 17. A forced air cooling system comprising a plurality of the forced air cooling apparatus of any one of claims 1 to 10.

25

30