(12) UK Patent Application (19) GB (11) 2 444 981 (13) A

(43) Date of A Publication 25.06.2008

(21) Application No: 0625281.1

(22) Date of Filing: 19.12.2006

(71) Applicant(s):
Ove Arup & Partners International Limited
(Incorporated in the United Kingdom)
13 Fitzroy Street, London, W1T 4BQ,
United Kingdom

(72) Inventor(s):
Roger Olsen

(74) Agent and/or Address for Service:
Frank B Dehn & Co.
St. Bride's House, 10 Salisbury Square,
LONDON, EC4Y 8JD, United Kingdom

(51) INT CL:
H05K 7/20 (2006.01) ***G06F 1/20*** (2006.01)

(56) Documents Cited:
US 20060260338 A1 **US 20060139877 A1**
US 20040065097 A1 **US 20030050003 A1**

(58) Field of Search:
UK CL (Edition X) **H1R**
INT CL **G06F, H05K**
Other: **EPODOC, WPI**

(54) Abstract Title: **Computer cooling system**

(57) A cooling apparatus for cooling computer racks 1 comprises a cooling unit 2 between two computer racks 1, a cold aisle 3 on either side of the cooling unit 2 between the cooling unit 2 and the computer rack 1, and a hot aisle 4 on the opposite side of the computer rack 1 to the cold aisle 3, wherein the apparatus is arranged such that chilled air generated by the cooling unit 2 passes into the cold aisles 3, flows through the racks 1 providing cooling and exits into the hot aisles 4. Alternatively, a cooling apparatus for cooling computer racks 1 comprises a cooling unit 2, a computer rack 1 and an enclosed cold aisle 3 for allowing passage of chilled air from the cooling unit 2 to the computer rack 1. The enclosed cold aisle prevents mixing of cool air with warm air from the hot aisles.

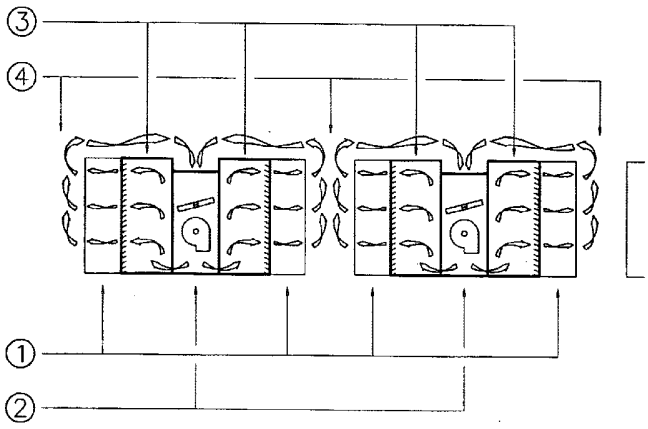

Figure 1

GB 2 444 981 A

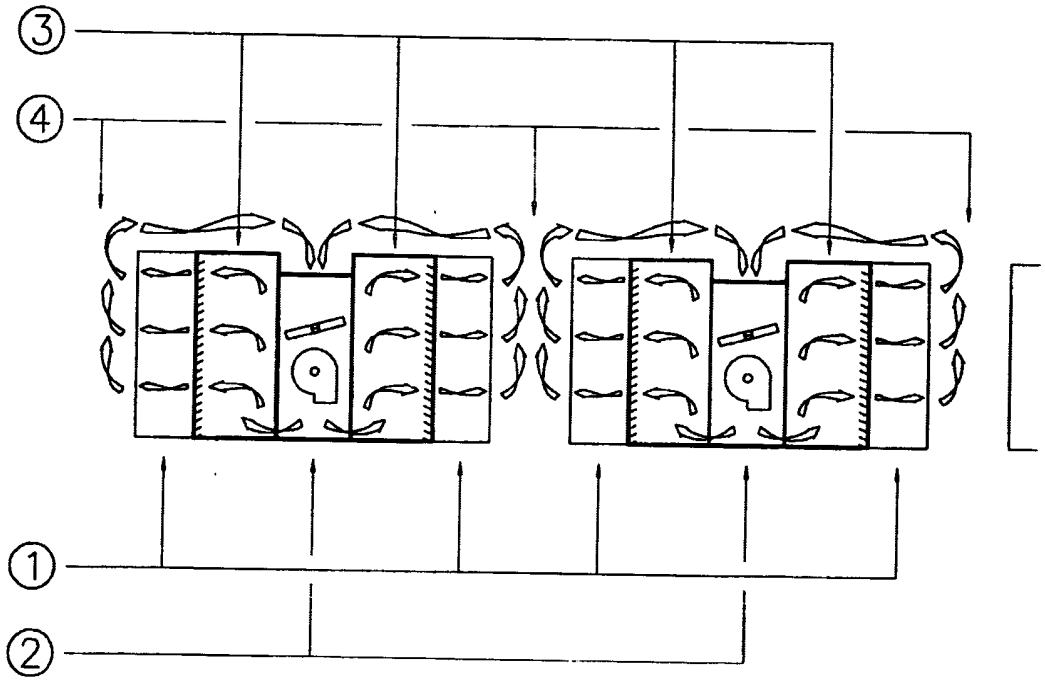

Figure 1

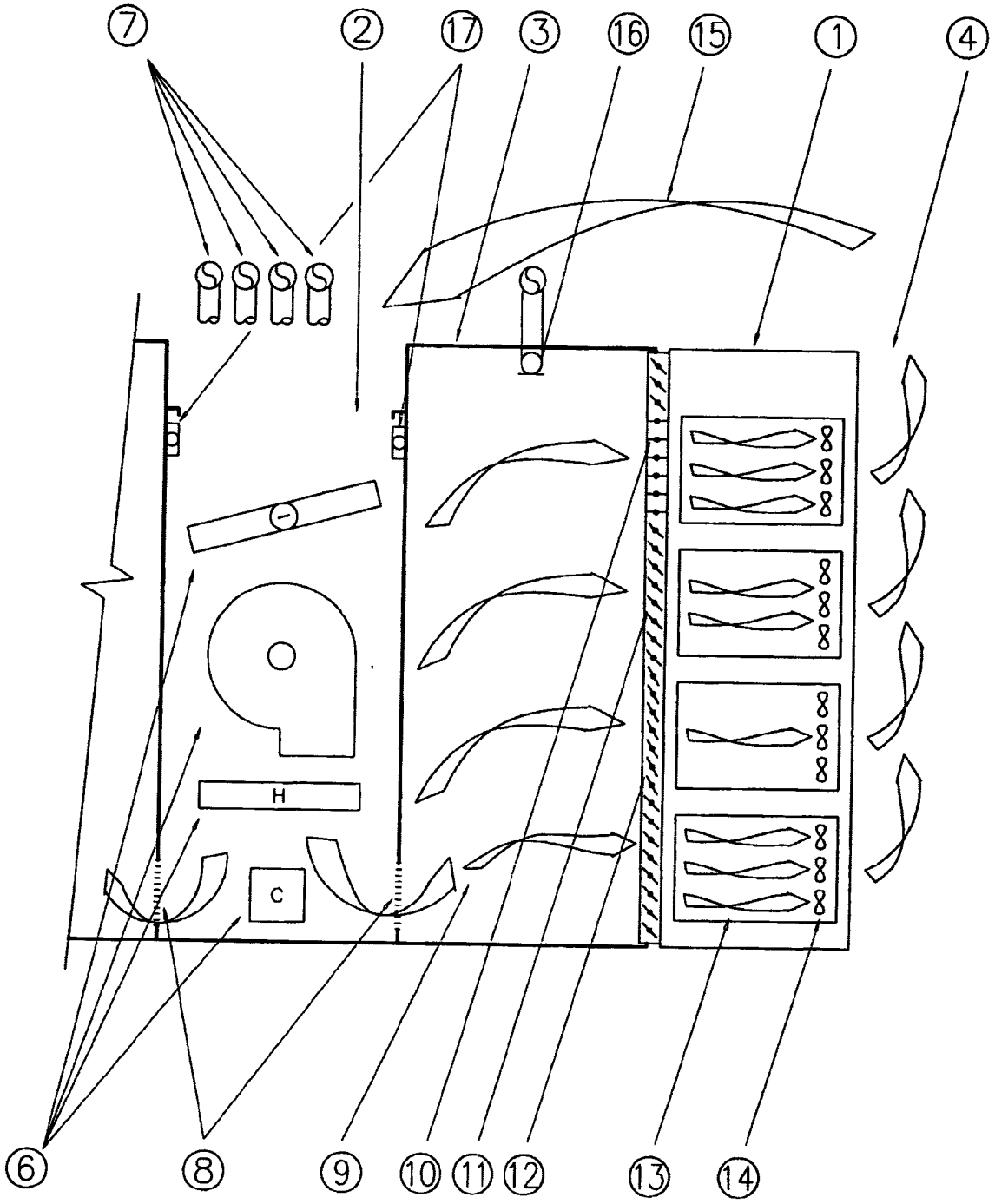

Figure 2

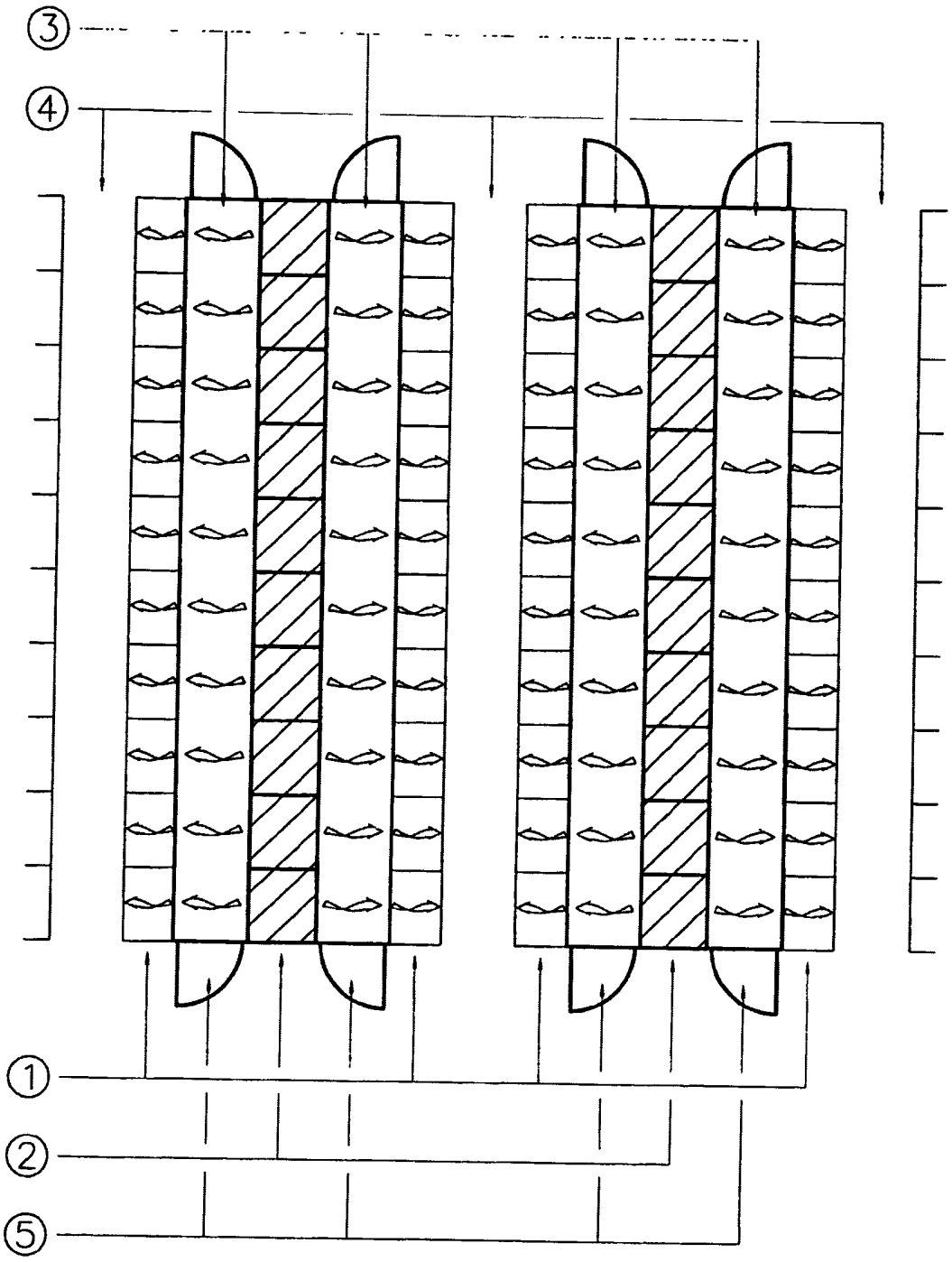

Figure 3

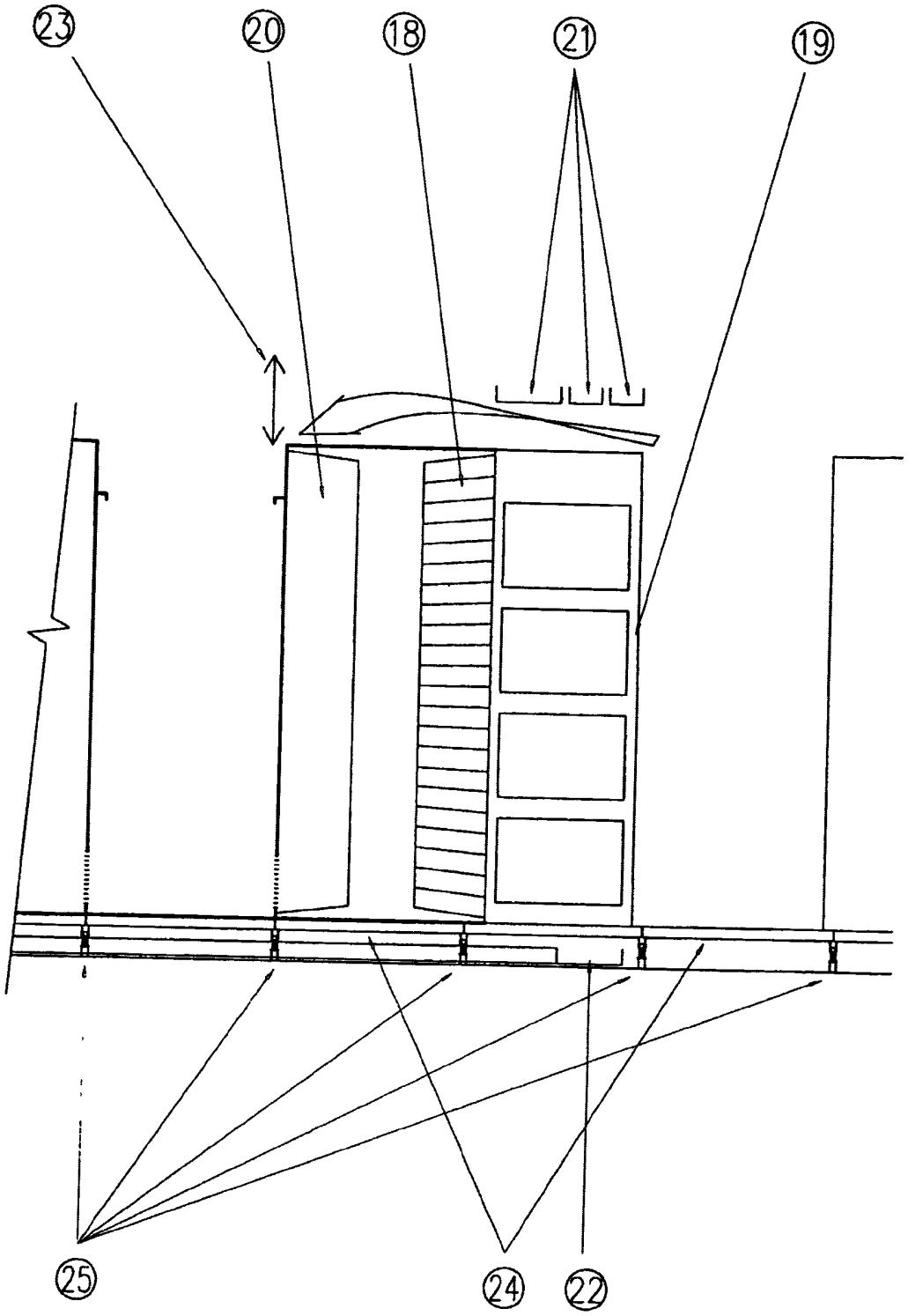

Figure 4

COMPUTER COOLING SYSTEM

This invention relates to a cooling apparatus for computer equipment, for example computer racks in a computer room or data centre.

The system traditionally used for cooling of data centres uses Computer Room Air Conditioning (CRAC) units, which blow chilled air down into a raised floor void. The chilled air then flows evenly through the floor void, and then upwards to cool the computer racks. The air flow inside the computer rack may be of:

i. the upflow type, where the chilled air flows upwards, into the bottom of the rack and out of the top, or

ii. the cross flow type, where air passes horizontally from one side of the computer rack to the other. Chilled air passes from the floor void via floor diffusers into the 'cold aisle' on one side of the computer racks. From here it is pulled across the computer racks by the computer fans, into the 'hot aisle', and from there passes back to the CRAC unit.

A typical arrangement is for a number of computer racks, from 20 to 200 or more, arranged in rows in the centre of a data centre, and for CRAC units and power supply units to be arranged round the perimeter of the data centre.

For a conventional cooling load of 1.6kW/rack this arrangement works well. If the cooling load is higher than this, the quantity of cooling air can be increased. However above approximately 6 to 7 kW/rack the satisfactory arrangement of the air flow pattern breaks down. Hot air from the hot aisle travels across the top of the racks and 'pollutes' the cold aisle with hot air. The computers at the top of the rack therefore draw in hot air from the cold aisle, and may overheat. The overheating may damage the computers and cause them to shut down, and it is possible that in extreme cases it could lead to a fire.

Existing cooling systems cannot cope with current requirements for high density cooling. High density cooling means that the power input and cooling loads are exceptionally high, up to 25kW per rack, compared with 1.6 kW/rack, a figure commonly used in data centres up to approximately the year 2000.

Other shortcomings with current data centre cooling systems include:

Inability to deal with uneven loading of computer racks - some racks may have a high density load, while neighbouring racks have a low density load. The cooling system may be capable of dealing with the average load, but cannot cope with the peaks from high density equipment;

Concern about leakage of water where chilled water is used as a cooling medium inside air conditioning unit coils;

Poor resilience, with little provision of 'back up' or 'standby' cooling units, which operate when other cooling units have failed and ceased to work. This applies particularly with cooling systems which are built into the sides or tops of racks;

Elevated operating temperatures, near or above the top of the range recommended by the manufacturers. One industry guide, the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.) Guide, Design Considerations for Datacom Equipment Centres 2005, recommends 20°C to 25°C for the inlet temperature for equipment, whereas some cooling systems offer 27 °C as the inlet temperature, and up to 40°C as the outlet temperature. Conventional designs have used 14°C as the inlet temperature and 22°C as the outlet temperature. The reason for the elevated temperatures appears to be that this permits a substantially higher cooling output for a given size of cooling device, compared with the lower temperature range;

Congestion of the raised floor void with data cables, leading to much reduced air flow, and consequent overheating; and

Expense and complication of a raised floor with a void below. The void may be used for cooling air, and for data or power cables.

Viewed from a first aspect, the present invention provides a cooling apparatus for computer equipment comprising a cooling unit disposed between two computer racks; a cold aisle on each side of the cooling unit between the cooling unit and the computer racks, and a hot aisle on each of the opposite sides of the computer racks to the cold aisle, wherein the apparatus is arranged such that chilled air generated by the cooling unit passes into the cold aisles, flows through the racks providing cooling and exits into the hot aisles.

The computer equipment will typically be equipment in a data centre or server room. The terms 'cold aisle' and 'hot aisle' take their usual meaning in the art. Thus 'cold' refers to the chilled air which enters the computer racks, with inlet temperatures as discussed above for example, and 'hot' refers to the warmer air which exits the computer racks at the outlet temperatures discussed above. The aisles are spaces between the racks and other equipments, and are generally sized to allow a person to access the racks from the aisle.

Thus, the central cooling unit can cool the racks on either side without the need for a floor void to transfer chilled air. Instead, chilled air is efficiently distributed to the racks using the arrangement: hot aisle – rack – cold aisle – cooling unit – cold aisle – rack – hot aisle. In contrast to the prior art coolers located about a perimeter of a data centre, the use of cooling units located between pairs of racks allows cooling to be provided evenly to racks at all locations within the data centre, and problems with locating cooling units. Generally, servers and the like on computer racks will draw air in on one side and exhaust air from the other side. Thus, racks can be placed with the air input side facing the cooling units and all racks in a data centre can therefore draw air in directly from the cooling units. This arrangement gives the intensity of cooling required for high density cooling, and avoids the need for supplementary cooling units on the rear doors of racks or suspended over racks. The apparatus can advantageously be used with any rack manufacturer; and can be used with a wide range of inlet and outlet temperatures for the racks, such as 12/22°C, 20/28°C, 25/35°C.

Air is preferably cycled around the cooling apparatus, with air from the hot aisle being returned to the cooling unit. The return path may be over the top of the cold aisle, and the return air supply to the cooling unit may be at an elevated location. Preferably the air is cycled using a cross flow of air horizontally through the computer racks between the hot and cold aisles. With air being cycled from the hot aisles over the cold aisles and back to the cooling unit the arrangement of hot aisle – rack – cold aisle – cooling unit – cold aisle – rack – hot aisle can be repeated without adverse effect, leading to two or more repeated rows of cooling units and racks within a data centre. This repeatable cooling apparatus capable of high capacity cooling can thus be advantageously adapted to fit any data centre, and in particular it can provide effective cooling to any size of data centre.

Preferably the apparatus is for cooling high density computer racks in a data centre. The cooling unit may be any suitable type of cooling unit, but is preferably an air conditioning unit, more preferably a Computer Room Air Conditioning unit (CRAC) of conventional type as used in existing data centre cooling systems.

There may be a plurality of cooling units in a row, and there may be a plurality of racks in a row either side of the cooling unit(s). In a preferred embodiment, some of the cooling units in a row are used as stand-by units. These cooling units provide cooling capacity in addition to the capacity required in the normal operation of the apparatus and

can be activated in the event of a breakdown or unexpected additional loading. The use of back-up cooling units thus provides good resilience and extra standby capacity in the cooling system. Where the number of units required for the load is 'n', the additional units to provide resilience can be expressed as 'n+1', 'n+2' etc. For this embodiment, the number of back up units can be a choice of n+1, n+2, n+3, 2n, for example.

In a preferred embodiment the cooling unit is a downflow cooling unit with chilled air passing from the cooling unit into the adjacent cold aisles at a low level. This aids in avoiding pollution of the chilled air by hot air from the hot aisle or in the returning air path. The cooling unit may be directly connected to the cold aisle, thus avoiding any heat transfer from the cold air before it enters the cold aisle.

Preferably a low level grille is used to transfer air from the cooling unit into the cold aisle. A raised floor is therefore not needed for the cooling system, although it can still be provided for cabling. This overcomes the problem of the floor void becoming so full with data cabling that there is no room for air flow.

There may be a simple grille or perforated plate between the cold aisle and the racks to distribute air evenly to the racks. However, preferably the apparatus includes air flow control dampers between the cold aisle and the racks. This allows the distribution of air to be controlled, and by adjusting the dampers the flow of cold air to particular racks can be varied. Thus, racks can be supplied with the optimal amount of cooling air and the apparatus can handle uneven loading of computer racks. Preferably the dampers allow the air flows to be adjusted to achieve 0% up to 100% of the peak cooling load. The dampers may allow cooling air to racks requiring a high level of cooling to be up to three times the average cooling. There may be several sets of control dampers which can be changed independently to control the air flow to different parts of a rack or to different racks in a plurality of racks.

Preferably refrigerants are used for cooling within the cooling unit instead of chilled water. R407C is a suitable refrigerant. This avoids the presence of water in the data centre and removes the risk of water leaks which could damage the computer equipment.

There may be an additional parallel cooling unit or additional parallel row of cooling units. This increases the cooling capacity and allows the apparatus to be used with computer racks where a higher cooling capacity is required. Thus with this high

capacity apparatus is in the arrangement: hot aisle – rack – cold aisle – cooling unit – cooling unit – cold aisle – rack – hot aisle.

The apparatus may include an enclosed cold aisle or an enclosed hot aisle. This prevents any risk of pollution of the chilled air flow by returning hot air. It is particularly preferable that the cold aisle is enclosed, as this allows more direct movement of cold air from the cooling unit to the computer rack. The hot air may then return to the cooling unit over the top of the computer rack in a natural circulation pattern with the less dense hot air above the enclosed chilled air.

This concept is considered to be inventive in its own right and therefore, viewed from a second aspect, the present invention provides a cooling apparatus for computer equipment comprising a cooling unit, a computer rack and an enclosed cold aisle for directing chilled air from the cooling unit to the computer rack.

The enclosed cold aisle between the cooling unit an the rack provides an enclosed air flow path that contains and directs the air flow, removing the possibility of short circuiting the air flow, or polluting the chilled air with hot air from a hot aisle or a returning hot air path. The use of an enclosed cold aisle is particularly advantageous where the returning hot air path is over the top of the cold aisle.

The cold aisle may be enclosed by a lid, floor and end panels. The end panels may be doors allowing access to the enclosed cold aisle.

The enclosed aisle may be a complete manufactured system, consisting of sections of lid, floor panels, end panels or end doors and frames, and a side panel adjacent to the rack. The side panel may be a door allowing access to the rack and the computers on the rack. Alternatively, the enclosed cold aisle may consist of just lid sections and end panels or end door and frame sections, which can be fitted to computer racks and floor sections already present, which then form the side and floor panels enclosing the aisle.

The preferred features discussed above in relation to the first aspect may be used with a cooling apparatus incorporating the enclosed cold aisle. This cooling apparatus may have a symmetrical arrangement, with cold aisle and racks either side of the cooling unit as in the first aspect of the invention, but the cold aisle may also advantageously be used in any conventional data centre cooling apparatus arrangement.

Viewed from a third aspect the present invention provides a method of manufacturing a cooling apparatus for computer equipment comprising: installing a

cooling unit between two computer racks; providing a cold aisle on either side of the cooling unit between the cooling unit and the computer racks, and providing a hot aisle on each of the opposite sides of the computer racks to the cold aisle, wherein the apparatus is arranged such that chilled air generated by the cooling unit passes into the cold aisles, flows through the racks providing cooling and exits into the hot aisles.

The method may include providing the preferred features of the apparatus of the first or second aspects of the invention.

In one preferred embodiment manufacturing the cooling apparatus comprises installing the cooling units and providing the cold and hot aisles about existing computer racks. In an alternative embodiment the computer racks as well as the other components are installed together.

Viewed from a fourth aspect the present invention provides a method of manufacturing a cooling apparatus for computer equipment comprising providing an enclosed cold aisle between a cooling unit and a computer rack, the enclosed cold aisle being for directing chilled air from the cooling unit to the computer rack.

The method of the fourth aspect may include providing the preferred features of the apparatus of the first or second aspects of the invention, and may be combined with the method of the third aspect of the invention.

In one preferred embodiment manufacturing the cooling apparatus comprises providing the enclosed cold aisle to allow passage of air between an existing cooling unit and computer rack. In an alternative embodiment the enclosed cold aisle may be provided at the same time as installing a cooling unit and a computer rack.

Certain preferred embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a general arrangement, in section, and shows principle of the CRAC units alternating with the racks,

Figure 2 is a detail from Figure 1, showing the components of the CRAC and rack,

Figure 3 is a plan view of the general arrangement shown in Figure 1, and

Figure 4 is another detail in section, and shows facilities for cabling, and maintenance access.

Figure 1 is a section of the arrangement of the data centre/ computer room. At full scale the portion shown would be approximately 14 metres wide and 3 metres high. The arrangement is "2+1", giving rack – CRAC – rack – rack –CRAC – rack. The use of racks on either side of cooling units provides a repeatable unit that enables the cooling capacity of the system to be increased. The racks 1 are arranged in rows, with the CRAC units 2 between pairs of rows. Adjacent to the CRAC 2 on each side is the enclosed cold aisle 3, which receives chilled air from the CRAC units 2. The chilled air passes from each enclosed cold aisle 3 to the adjacent rack 1. The air then passes horizontally through the rack into the hot aisle 4, and from there passes back over the top of the rack 1 and the enclosed cold aisle 3 to the CRAC unit 2.

An alternative to this arrangement is to provide double the number of CRACs, in order to double the cooling capacity. The arrangement would therefore be hot aisle – rack – cold aisle – CRAC- CRAC- cold aisle- rack – hot aisle. This arrangement is referred to elsewhere as the high capacity system.

Figure 2 is a detail from the section arrangement in figure 1. A number of components 6 are shown in the CRAC, chilled water coil, drip tray, condensate pump, fan, humidifier, reheater, compressor and controls. The exact arrangement of these components 6 may vary between different CRAC manufacturers, and other components such as air filters may also be provided. These components provide the chilled and humidified/ dehumidified air to the supply grille 8 at the bottom. The pipe work 7 located above the CRAC provides refrigerant flow and return to the compressor, and water supply and condensate return.

The chilled air 9 passes into the enclosed cold aisle 3 and distributes across the face of the racks. Small control dampers 10, 11, 12 regulate the air passing into different parts of the rack 1, and can be changed to different settings. In Figure 2, the upper control dampers 10 are shown fully open, permitting the maximum amount of air to pass into the rack 1, and this would be appropriate for the highest density cooling load computer equipment. The middle control dampers 11 are partly closed, and would be appropriate for average density cooling load computer equipment. The lower control dampers 12 are almost completely closed, and this would be appropriate for low or zero density cooling load computer equipment. It will be appreciated that the dampers 10, 11, 12 can be set depending on the computer equipment used on the racks in order to provide optimum

cooling for. Each rack can be provided with its own set of dampers 10, 11, 12 and different racks can have different damper settings.

Inside the racks 1 the computer servers are shown as a box 13 each with its own cooling fan 14, which assists in drawing air across the servers. As the air passes across the servers it cools them, and becomes hoter before passing into the hot aisle 4.

Computer servers usually have their display face or control panel on the inlet air side, and in this arrangement they face the enclosed cold aisle 3. The door containing the control dampers allows access to the computer control panels, and an option is to make the control dampers of translucent material to permit the computer control panels to be visible without opening the door.

Another option is to reverse the air flows, to make the enclosed aisle the hot aisle, use an upflow CRAC unit 2, and draw in cold air via the unenclosed aisle. The computer servers would then be reversed to make their control panel face the unenclosed cold aisle.

In the hot aisle 4 the air flows upwards and then the return air 15 passes over the top of the rack 1 and the enclosed cold aisle 3 back to the inlet on top of the CRAC 2.

The lid on the enclosed cold aisle 3 may affect the operation of conventional water sprinklers, and it may be necessary to install additional sprinklers heads 16 below the lid. If a fire suppression system using gas is used, then supplementary sprinklers heads 16 will probably not be required.

The lighting and emergency lighting is provided in the enclosed cold aisle 3 by light fittings 17 built into the CRAC 2. An alternative to this is to provide translucent lids to the cold aisle 3 to permit light from the data centre into the enclosed cold aisle 3.

Figure 3 is a plan view of the arrangement shown in figure 1, and to the same scale shown. At full scale the portion shown would be approximately 14 metres by 12 metres. The chilled air passes from the CRACs 2 to enclosed cold aisles 3, and then into the racks 1, finally passing into the hot aisles 4. The enclosed cold aisles 3 have air tight doors 5 at the ends of the rows to complete the enclosure. The design can be increased in size by adding more racks 1 and CRACs 2 to the ends of the rows, or by adding more 2+1 rows of rack-CRAC-rack.

Figure 4 is another detail from the section arrangement in figure 1. The figure illustrates how access can be provided to computer racks 1, cable trays for power and data, and CRAC units 2 in the same way as a conventional data centre. Access to the

computer servers in the racks 1 is provided via opening doors 19 from the unenclosed aisle, and via opening doors 18 in the enclosed aisle (shown partly open). Access to the CRAC units 2 for maintenance is provided via opening doors 20 in one of the enclosed aisles 3 (shown partly open).

Cable routes for power or data are via cable trays 21 above the racks 1, or inside the racks 1. An alternative location for cable trays is in a floor void 22, although this raised floor and void is not required for the cooling system. Accessible floor tiles 24, supported by floor pedestals 25, in the enclosed and unenclosed aisles provide access to the raised floor void.

With the use of the cooling system described above, peak cooling loads of up to 30 kW/rack or an average of 10 kW/rack should be achievable. If increased cooling capacity is required, then a high capacity system can be utilised, which has an additional CRAC 2, and is thus in the configuration Hot aisle – rack – cold aisle – CRAC- CRAC- cold aisle- rack – hot aisle. With this arrangement, peak cooling loads of up to 40kW/rack, or an average of 20 kW/rack should be achievable.

CLAIMS:

1. A cooling apparatus for computer equipment comprising a cooling unit disposed between two computer racks; a cold aisle on each side of the cooling unit between the cooling unit and the computer racks, and a hot aisle on each of the opposite sides of the computer racks to the cold aisle, wherein the apparatus is arranged such that chilled air generated by the cooling unit passes into the cold aisles, flows through the racks providing cooling and exits into the hot aisles.

2. A cooling apparatus as claimed in claim 1, wherein the air is cycled around the cooling apparatus, with air from the hot aisle being returned to the cooling unit over the top of the cold aisle.

3. A cooling apparatus as claimed in claim 1 or 2, comprising a plurality of cooling units in a row.

4. A cooling apparatus as claimed in claim 4, wherein at least one of the cooling units is used as a stand-by unit.

5. A cooling apparatus as claimed in any preceding claim, wherein the cooling unit is a downflow cooling unit with chilled air passing from the cooling unit into the adjacent cold aisles at a low level.

6. A cooling apparatus as claimed in any preceding claim, comprising air flow control dampers between the cold aisles and the racks.

7. A cooling apparatus as claimed in claim 6, comprising several sets of control dampers which can be changed independently to control the air flow to different parts of a rack or to different racks in a plurality of racks.

8. A cooling apparatus as claimed in any preceding claim, comprising parallel cooling units between the racks.

9. A cooling apparatus as claimed in any preceding claim, comprising an enclosed cold aisle for allowing passage of chilled air from the cooling unit to the computer rack.

10. A cooling apparatus for computer equipment comprising a cooling unit, a computer rack and an enclosed cold aisle for directing chilled air from the cooling unit to the computer rack.

11. A cooling apparatus as claimed in claim 9 or 10, wherein the cold aisle is enclosed by a lid, a floor and end panels.

12. A cooling apparatus as claimed in claim 9, 10 or 11, wherein the enclosed aisle comprises a lid section, a floor panel, end panels, and a side panel adjacent the computer rack.

13. A cooling apparatus as claimed in claim 9, 10 or 11, wherein the enclosed aisle comprises a lid section and end panels, which can be fitted to computer racks and floor sections already present to thereby enclose the cold aisle.

14. A method of manufacturing a cooling apparatus for computer equipment comprising: installing a cooling unit between two computer racks; providing a cold aisle on either side of the cooling unit between the cooling unit and the computer racks, and providing a hot aisle on each of the opposite sides of the computer racks to the cold aisle, wherein the apparatus is arranged such that chilled air generated by the cooling unit passes into the cold aisles, flows through the racks providing cooling and exits into the hot aisles.

15. A method as claimed in claim 14, comprising providing an apparatus as claimed in any of claims 1 to 13.

16. A method as claimed in claim 14 or 15, wherein manufacturing the cooling apparatus comprises installing the cooling units and providing the cold and hot aisles about existing computer racks.

17. A method as claimed in claim 14 or 15, wherein manufacturing the cooling apparatus comprises installing the cooling units and providing the cold and hot aisles at the same time as installing the computer racks.

18. A method of manufacturing a cooling apparatus for computer equipment comprising providing an enclosed cold aisle between a cooling unit and a computer rack, the enclosed cold aisle being for directing chilled air from the cooling unit to the computer rack.

19. A method as claimed in claim 18, comprising providing an apparatus as claimed in any of claims 1 to 13.

20. A method as claimed in claim 18 or 19, wherein manufacturing the cooling apparatus comprises providing the enclosed cold aisle between an existing cooling unit and an existing computer rack.

21. A method as claimed in claim 18 or 19, wherein manufacturing the cooling apparatus comprises providing the enclosed cold aisle at the same time as installing the cooling unit and the computer rack.

22. A cooling apparatus substantially as hereinbefore described with reference to the accompanying drawings.

23. A method of manufacturing a cooling apparatus substantially as herein before described with reference to the accompanying drawings.

The Patent Office

For Innovation

13

Application No: GB0625281.1 **Examiner:** Ian Rees

Claims searched: 1 to 17 **Date of search:** 14 March 2007

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	US 2006/0260338 A1 VAN GILDER. See abstract.
A	-	US 2006/0139877 A1 GERMAGIAN. See figure 1.
A	-	US 2003/0050003 A1 CHARRON. See figure 1.
A	-	US 2004/0065097 A1 BASH. See paragraph 0020.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

H1R

Worldwide search of patent documents classified in the following areas of the IPC

G06F; H05K

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI