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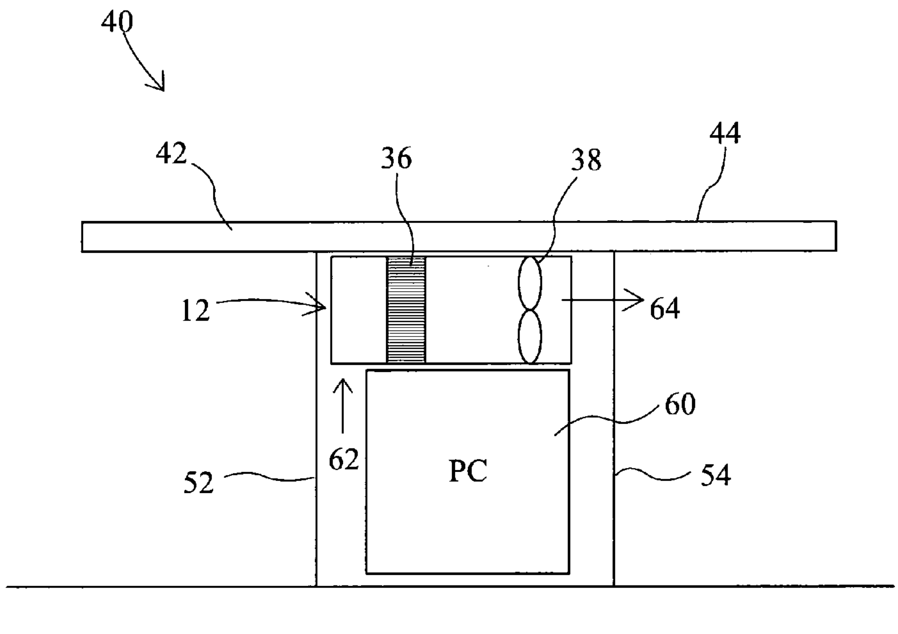
(54) **Title:** COOLING APPARATUS AND METHODS FOR COOLING



(57) **Abstract:** A workstation cooling unit (12), comprises a heat transfer path adapted to contain a heat transfer fluid, the heat transfer path being adapted for connection to a condenser to form a heat transfer circuit, and a heat exchanger (36) for cooling the workstation (40). In this way, direct cooling of a workstation (40), for example a desk or other work area, can be achieved. The heat transfer fluid may comprise carbon dioxide.

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Cooling Apparatus and Methods for Cooling

This invention relates to methods and apparatus for cooling. Particularly, but not exclusively, aspects of this invention relate to the cooling apparatus and methods in the field of information technology. Preferred examples of aspects of the invention relate to the cooling of information technology apparatus, in particular computer equipment such as personal computers and/or servers and has particular (but not exclusive) relevance to the cooling of computers and/or servers which are located in the region of workstations.

It is common, for example in office environments, for personal computers to be stored at workstations or desks; in an office, each worker's computer equipment is often stored underneath their desk. In some office environments, several items of computer equipment may be stored under each desk or workstation. For example in a bank trading floor environment, it is not uncommon for each workstation to house several computers. Such computer equipment generates heat when operational and such heat can be concentrated under the workstation where the equipment is mounted.

In a typical office environment, an air conditioning system supplies cool air from an overhead distribution system. The distribution system typically employs air or water that is either ducted or piped to the room that is the location for the workstations.

However, by locating the heat-generating equipment under workstations, the equipment is often not exposed directly to the cool air supplied by the air conditioning system. The workstation itself can impede the supply of cool air to the equipment. This problem can be compounded due to heat generated by the equipment which may currently be up to 1.5 kW or even 5 kW per workstation, for example desk, which may become trapped under the workstation to create a hot chamber.

Under floor air systems have been used in an attempt to provide an adequate supply of cool air to equipment. In such an arrangement, rather than air being supplied from above, it is supplied to the equipment from grilles in a false floor. For example, the office cooling system may comprise a combination air/water system: water being the primary coolant and air being the secondary coolant. Cooled air is pumped by fans into the floor void beneath the equipment and released into the room through grilles sited appropriately around the floor. Air is electrically benign and inherently safe, which makes it a highly attractive coolant for use in such systems.

However, as transistors have become smaller, and chip capacity has grown, the power dissipation requirements of IT or computing equipment has grown. Modern equipment can require a large volume of air to achieve the desired cooling. Thus a disadvantage of these systems is that in order to provide the desired cooling, the systems can create excessive air velocities at floor and ankle level. This can make the environment unpleasant to work in. Raised floor voids may also need to be increased to accept the large supply air through the floor in the form of a pressurized floor plenum. In view of the high heat outputs of some equipment it may be that air cooling is not adequate to provide sufficient cooling of the equipment, which might lead to malfunction and/or issues of safety of electronic components in the equipment.

Aspects of the present invention seek to provide cooling apparatus which mitigates one or more of the above-mentioned disadvantages.

According to a first aspect of the invention, there is provided a workstation cooling unit, the unit comprising: a heat transfer path adapted to contain a heat transfer fluid, the heat transfer path being adapted for connection to a condenser to form a heat transfer circuit, and a heat exchanger for cooling the workstation.

According to this aspect of the present invention, direct cooling of a workstation can be achieved.

In particular preferred examples of aspects of the invention referred to herein, a workstation comprises equipment, in particular heat-generating equipment, for example computer equipment for a user located at a desk or other work area. Where reference is made to the term workstation herein, preferably the term is to be interpreted as including (unless clear from the context to the contrary) a desk or other work area, in particular where that desk or work area includes heat-generating equipment. In particular arrangements, the workstation is arranged such that the equipment is for use by a single user or small number of users at that desk or work area. This is to be contrasted, for example, from computer equipment located in a specialist work room, for example a server room. It is noted that, in contrast to most workstations, such rooms are rarely inhabited by users, except for during maintenance.

Particular reference is made herein to IT and computer equipment, and in particular personal computers, but it will be understood that aspects of the invention are applicable to the cooling of other equipment. Particular preferred examples relate to the cooling of office equipment.

Thus arrangements according to aspects of the present invention can be used to provide cooling to individual user work areas. Preferred examples described in more detail below comprise cooling systems arranged to cool a plurality of separate workstations or groups of workstations.

In some such arrangement, each cooling unit may be arranged to cool a separate workstation, for example with a separate heat exchanger being provided for each workstation. In other arrangements, each unit may be arranged to provide cooling for several workstations.

Where reference is made herein to cooling a workstation, preferably that reference includes (unless it is clear from the context to the contrary) cooling a part of the workstation and/or cooling equipment mounted at or in a part of the workstation.

Preferably the heat transfer fluid comprises a volatile fluid. Localised cooling systems utilising chilled water can be employed in accordance with aspects of this invention to provide enhanced cooling. In such an arrangement, chilled water is piped to a heat exchanger at the relevant location by the workstation (optionally a fan can be used to blow air over cold pipe work to enhance cooling). Such arrangements can have an advantage over air-based solutions since the size of the distribution pipe work can be less when compared with air ducts required to achieve equivalent cooling with an air-based system. However, the use of chilled water as a coolant within an office environment, in particular when local to electrical equipment, is considered disadvantageous in some respects. Water presents a risk or perceived risk to the equipment as a result of water leakage since water is a conductor of electricity.

Furthermore, by using a volatile fluid as the heat transfer fluid, more efficient cooling of the workstation can be obtained: greater cooling can be obtained from exploiting the evaporation of a volatile fluid compared with the use of a non-volatile fluid.

Preferably the heat transfer fluid comprises carbon dioxide. The use of carbon dioxide as a coolant fluid is known. Use of carbon dioxide as a secondary coolant fluid is known, being described in UK Patent Application No. 2 258 298. However, it has not previously been considered in the application of workstation cooling.

The volatile fluid, for example carbon dioxide, is electrically benign and may be used relatively safely in applications for cooling workstations, despite the high pressures required. For carbon dioxide, in examples described herein, the fluid pressure required is of the order of 50 Bar; this can provide a fluid circulating temperature of about 14 degrees C. By this arrangement, the system runs "dry" in normal operating conditions in that the temperature of the fluid is such that there is little formation of condensation on the pipe work. In some other applications, a lower operating temperature may be chosen to improve cooling efficiency, but measures will need to be taken to deal with resulting condensation, if necessary. For example, a drip tray and associated drain and pump may be provided.

The use of carbon dioxide as the volatile fluid can provide very energy efficient cooling. Also, the pipe diameters of the cooling system and the heat exchange surface areas can be reduced in size in comparison to systems using other coolant, for example air or water. Arrangements described herein can achieve loads of up to about 5 kW per workstation.

Other volatile fluids may be used. For example, the volatile fluid may comprise ammonia or HFC-134a.

Preferably the heat exchanger is adapted to be mounted at the workstation. In some examples, the unit comprises a heat exchanger located at the workstation. Preferably the heat exchanger is arranged such that direct cooling of the workstation is obtainable. In some arrangements the heat exchanger is adapted to be mounted at the workstation, for example close to heat-generating equipment of the workstation.

By mounting the heat exchanger at the workstation itself, various improvements may be made. For example, direct removal of heat from the equipment at the workstation can be achieved.

In some arrangements, the heat exchanger is mounted local to the workstation; in other arrangements, the heat exchanger is mounted in the workstation.

The heat exchanger may be positioned to any of the sides, above or below a workstation. The heat exchanger may be positioned to more than one, or indeed all sides of the workstation.

In some arrangements, the heat exchanger is adapted to be mounted at least partly in the workstation. In this way, a compact arrangement can be achieved, together with effective cooling of the workstation. The heat exchanger may be substantially wholly mountable within the workstation.

The cooling unit may be mounted local to the workstation, in the workstation, or adjacent the workstation, for example in the floor (above or below the floor) in the ceiling above or below the ceiling, or elsewhere.

The heat exchanger may be adapted to be mounted local to the workstation.

In some preferred arrangements, the heat exchanger may be mounted away from the workstation itself. In some preferred arrangements, the heat exchanger will be mounted in the floor beneath the workstation or in the ceiling above the workstation. In most practical arrangements, as discussed in further detail below, it will be necessary for a fan or other means for moving air across the heat exchanger to be provided. It is envisaged, however, that some arrangements may not include a fan or fans.

The cooling unit may be constructed having a suitable casing so that it may be installed in one or more possible locations, for example beneath a desk, floor mounted or ceiling mounted. The casing may include attachment portions for assisting with the installation or the cooling unit. Where the cooling unit is to be used as a floor-mounted unit, the cooling unit may be adapted so that it can replace a floor tile or multiples of floor tiles when installed, and can preferably be designed to withstand normal office floor loadings.

Preferably the heat exchanger includes a finned coil. A suitable construction for the heat exchanger will be chosen in accordance with, for example, the desired operating pressure of the heat exchanger. In some arrangements a copper pipe having aluminium fins will be used; in arrangements where the pressure of fluid in the coil is to be higher, a stainless steel pipe having aluminium fins or an aluminium ribbon extrusion having aluminium fins might be used. The coil may be pressure tested at or above 100 Bar for an arrangement intended to run at an operating pressure of 50 Bar. For an arrangement intended to run at a higher operating pressure, for example 100 Bar, the coil may be pressure tested to about 200 Bar. The evaporator may comprise interlaced coils with dual pipe work.

Although carbon dioxide is a relatively safe substance, at high concentrations it can be dangerous.

Preferably the cooling unit further includes leak detection apparatus for detecting leak of heat transfer fluid. Preferably the leak detection apparatus includes a gas detection monitoring chamber, and preferably the chamber is arranged such that the integrity of the heat exchanger and/or pipe work and/or other parts of the unit can be monitored. Preferably the system is provided with an automatic shut off safety device to isolate the supply of carbon dioxide to the unit, and/or take appropriate action with regard to the computer equipment, for example effecting shut down of the equipment and/or sending a warning message.

Preferably the cooling unit further includes a fan adapted to move air over the heat exchanger. Generally, the preferred option is for a fan to be included, although it is envisaged that some arrangements might not include a fan.

By arranging a fan to move air over the heat exchanger, greater cooling can be obtained. Furthermore, it is possible to obtain cooling of equipment where the equipment is not arranged directly adjacent the heat exchanger.

Preferably the heat exchanger is arranged in an air channel. Preferably the heat exchanger is arranged to be at an angle to the direction of air flow in the channel. In this way, air can be arranged to pass through the heat exchanger, for example through the coils of a heat exchanger, thereby achieving more efficient cooling.

Preferably the fan is arranged to move air along the channel, preferably to blow warm air along the channel.

In some arrangements, a fan is mounted in the air channel; by this method, the air may be moved efficiently through the air channel. However, in other arrangements, the fan may be mounted outside of the channel.

The unit may include a plurality of air channels. This feature can give greater flexibility in directing the air within the apparatus and thus can lead to more efficient cooling. In preferred arrangements, a heat exchanger may extend through several air channels.

In some arrangements, the heat exchanger is mounted in an air chamber, the apparatus further comprising a dividing member for dividing the air chamber to form a plurality of air channels. The dividing member conveniently comprises a plate used to section off part of the air chamber to form air channels.

In some arrangements, the unit further includes a housing having an air inlet and an air outlet, the fan being arranged for moving air from the inlet to the outlet.

Preferably the unit further includes an air directing formation. Preferably the air directing formation extends from the heat exchanger towards the heat-generating equipment. In preferred arrangements, the air directing formation terminates adjacent to, but preferably not fixed to, the heat source. In this way, the hot air from the heat-generating equipment may be more efficiently directed to the heat exchanger. Where the heat exchanger is arranged in a channel or housing, preferably the air directing formation is adapted to direct air from the equipment to an inlet region of the channel or housing.

Preferably the air directing formation includes a duct for directing the air. The air directing formation, for example duct or hose, may be associated with and/or mounted adjacent an air outlet of the heat-generating equipment and be arranged to direct air towards the heat exchanger. Preferably the duct further includes an inlet formation, wherein the inlet formation is adapted to enclose an outlet of the equipment. In this way, efficient collection of warm air exiting the equipment into the duct can be achieved. The inlet formation may include a funnel for directing the air. The hose end or funnel is preferably shaped so that it cannot effect a seal with the heat source; this enables additional air to flow into the device when required, for example when the air flow associated with the heat source is less than the suction fan duty. Alternatively, or in addition, orifices or air holes may be included in a part of the duct and/or inlet formation to allow air into the duct. In such an arrangement, the inlet formation may or may not be sealed to the heat source. The duct may include a plurality of inlet formations for enclosing a plurality of outlet regions of the equipment.

The duct may comprise a flexible hose. In this way, the duct can be arranged so that the inlet formation or formations can more easily enclose outlet regions of equipment, and a range of different equipment designs can be accommodated.

The fan may be arranged in the duct. It should be understood that the fan may comprise a plurality of fan elements. The fan may be arranged to direct air into the region where the heat exchanger is mounted so that the warm air from the equipment is directed across the heat exchanger.

Once the air has passed over the heat exchanger, it may be recirculated past the equipment and/or it may be vented to the atmosphere. A further air directing formation or duct may be used to direct the cooled air which has passed over the heat exchanger.

In some arrangements, further air directing formations or ducts may be arranged to direct air, preferably cool air (from the atmosphere or from a cooling system) to the equipment, for example to the air inlet of the equipment.

The fan may direct air into a cavity in the workstation or into a floor cavity, and/or may direct the air into the atmosphere.

Preferably the heat exchanger is adapted to be mounted beneath the workstation. In preferred arrangements, the heat exchanger is mounted in or adjacent a floor cavity underneath the workstation.

By arranging the heat exchanger under the workstation, efficient use of space can be achieved. Preferably the heat exchanger unit comprises a floor tile replacement unit.

The heat exchanger may be adapted to be mounted at or directly above floor level. In a workstation environment, the area under the floor tiles is often utilised for cables and other services being supplied to the workstations. It is thought that in some situations, there will be insufficient available space in the underfloor area for the heat exchangers to be mounted. By mounting the heat exchanger at or directly on the floor level, less space under the floor is utilised. In a preferred arrangement, the fluid supply is mounted under the floor, and the heat exchangers are mounted immediately above the floor level, directly under the workstations.

Preferably the heat exchanger unit is adapted to be mountable in a space intended for a standard floor tile. Thus individual floor tiles can be replaced with heat exchanger units where workstations are to be sited on the floors. Where several workstations are arranged, for example in a row, a corresponding row of floor tiles can be replaced by heat exchanger units arranged under the workstations.

In further examples, the heat exchanger unit is adapted to be mounted above the workstation. In this arrangement, the heat exchanger units are preferably adapted to be mountable in a space intended for a standard ceiling tile. Preferably the heat exchanger units are mounted in the space directly above a false ceiling. Ducts may be provided to direct air from the equipment to the heat exchangers.

The cooling unit may further comprise cable management formations. Such formations can be used to direct electrical or other cables in the workstation environment. The cooling unit may incorporate pre-formed cable channels such that it can easily be integrated into a heavily cabled desk or other workstation area while still allowing successful cable co-ordination.

The heat exchanger may be adapted to provide cooling for a plurality of workstations. In some arrangements, each heat exchanger may provide cooling for a plurality of items of equipment. Preferably the heat exchanger will extend so as to be local a plurality of workstations. In some arrangements, an array of air directing formations and/or ducts is provided to effect cooling of several workstation environments. One or more heat exchanger units may be provided for each array.

Preferably the cooling unit is adapted for use in a secondary heat transfer circuit of a cooling system. Preferably, the primary circuit includes an evaporator, an expansion device, a condenser and a compressor. Preferably the secondary circuit includes a heat exchanger, a pump, a condenser and an expansion device.

The invention also provides a cooling apparatus comprising a cooling unit as described herein and a condenser connected to the heat transfer path to form a secondary heat transfer circuit, the condenser being adapted to be cooled by a primary heat transfer circuit. The secondary heat transfer circuit contains, in use, a secondary heat transfer fluid which preferably comprises a volatile fluid, preferably carbon dioxide.

The secondary circuit may be operable at more than 25 Bar. Conveniently the secondary circuit is operable at about 50 Bar. In some arrangements, it will be preferred that the secondary circuit is operable at up to 100 Bar. Where the system comprises a primary-only circuit, the circuit may be operable at about 100 Bar.

Preferably the volatile fluid is carbon dioxide. The temperature of the carbon dioxide received at the secondary heat exchanger may be in the region of 0°C to 30°C and conveniently is in the region of 12°C to 16°C, preferably being substantially 14°C where the secondary circuit is arranged to run "dry" under normal operating conditions with the formation of condensation on the coil being discouraged. In some other applications, a lower operating temperature may be chosen to improve cooling efficiency, but measures will need to be taken to deal with resulting condensation, if necessary. For example, a drip tray and associated drain and pump may be provided.

The secondary heat transfer circuit may further include a pump, or may be gravity fed.

The unit may accept integrated carbon dioxide flow and return distribution pipe work or such pipe work may be located outside the housing or casing of the unit.

A further aspect of the invention provides a workstation cooling system comprising: a primary heat transfer circuit; a secondary heat transfer circuit for containing a secondary heat transfer fluid, a secondary condenser adapted to be cooled by the primary heat transfer circuit and a secondary heat exchanger for cooling the workstation.

Preferably, the secondary heat transfer fluid comprises a volatile fluid. Preferably the secondary heat transfer fluid comprises carbon dioxide. In preferred examples, the primary heat transfer fluid for the primary heat transfer circuit is not carbon dioxide; it may be chilled water, air, or other coolant for example ammonia.

Each heat exchanger may be arranged to provide cooling for one or more workstations. In this way efficient cooling of a large number of workstations can be achieved, even where the workstations are spaced apart.

Preferably the workstation cooling system comprises a plurality of cooling units as described herein. A plurality of cooling units may be contained in a single secondary heat transfer circuit or in a plurality of such circuits, or in a combination of these arrangements.

By providing localised cooling to workstations using cooling units, efficient cooling of the workstations can be effected, in preferred arrangements, to achieve safe working temperature of the equipment while avoiding discomfort to users located at the workstations, as might occur in an arrangement where high air flows were used to effect cooling.

According to a further aspect of the invention there is provided a cooling unit for cooling a workstation, the unit including an air inlet, an air outlet, an air duct and a heat exchanger for forming part of a secondary heat transfer circuit.

Preferably, in use a heat transfer fluid flowing in the heat transfer circuit is a volatile fluid.

The invention also provides a workstation adapted to house a cooling unit as described herein. Preferably the workstation includes a compartment for housing the cooling unit such that at least a part of the cooling unit is mounted in the compartment.

In some arrangements it is preferred that at least the heat exchanger of the unit can be mounted in the compartment. Preferably the compartment is adapted to house heat-generating equipment.

Preferably the compartment is such that the equipment is at least partly mounted in the compartment.

Preferably the workstation comprises heat-generating equipment, wherein the heat-generating equipment preferably comprises computer equipment.

The compartment may be adapted to be substantially sealed when the cooling unit and equipment are housed in the compartment. The compartment may provide some heat sealing function. In this way, heat generated by the equipment can be to some extent contained within the compartment, and thus can be more efficiently removed by use of the cooling unit.

Preferably, in such an arrangement, the compartment is sealed but is not air tight. The heat load is thus contained within a notionally sealed unit such that the heat may be successfully absorbed by the liquid carbon dioxide.

In an alternative arrangement, the compartment is provided adjacent to the workstation, for example in a floor cavity.

The compartment may comprise heat insulation. Heat load insulation screens may be utilised to form such a compartment. The screens may be formed from, for example, open or closed cell foam, faced mineral wool panels, plasterboard or other suitable panelling.

By mounting the unit in the compartment, the equipment can also be protected from physical damage.

Also provided by an aspect of the invention is a workstation comprising equipment to be cooled and a cooling unit for cooling the equipment, the unit comprising: a heat transfer path adapted to contain a heat transfer fluid, the heat transfer path being adapted for connection to a condenser to form a heat transfer circuit, and a heat exchanger for cooling the equipment.

Preferably the heat transfer fluid is a volatile fluid.

The heat exchanger may be mounted beneath the workstation.

The equipment may comprise computer equipment.

A further aspect of the invention provides a floor unit for mounting beneath a workstation area, the floor unit comprising a a heat transfer path adapted to contain a heat transfer fluid, the heat transfer path being adapted for connection to a condenser to form a heat transfer circuit, and a heat exchanger for cooling the workstation area.

Also provided by the invention is the use of a volatile fluid at a heat transfer fluid in an apparatus for cooling a workstation. Preferably the heat transfer fluid comprises carbon dioxide.

The invention also provides a method of cooling a workstation, the method comprising: circulating fluid through a heat transfer circuit to a heat exchanger disposed adjacent or in the workstation.

Also provided is a method of cooling a workstation, the method comprising: circulating fluid through a heat transfer circuit to a heat exchanger disposed such that the heat exchanger effects removal of heat from the workstation.

Where reference is made to cooling a workstation, preferably that reference is to include cooling equipment located in a workstation environment.

Preferably the heat transfer circuit comprises a secondary heat transfer circuit comprising a secondary condenser, and the method further comprises circulating fluid through a primary heat transfer circuit to effect cooling at the secondary condenser.

Also provided by the invention is a cooling unit, cooling apparatus, cooling system, or workstation being substantially as herein described having reference to any one or more of the accompanying drawings.

The invention also provides a cooling method, optionally for cooling a workstation or computer equipment, the method being substantially as herein described.

Any feature in one aspect of the invention may be applied to other aspects of the invention, in any appropriate combination. In particular, method aspects may be applied to apparatus aspects, and vice versa.

Preferred features of the present invention will now be described, purely by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows schematically a flow diagram of an example of a primary – only cooling system;

Figure 2 shows schematically a flow diagram of an example of a primary and secondary cooling system;

Figure 3 shows a perspective view of a workstation;

Figure 4 shows a schematic cross-sectional view of a workstation of a type illustrated in Figure 3;

Figure 5 shows an alternative arrangement of the workstation cooling unit;

Figures 6a, b and c show an example of a workstation arrangement having an under-floor mounted heat exchanger;

Figure 7 shows an alternative heat exchanger unit arrangement;

Figure 8 shows a further example of a heat exchanger unit;

Figure 9 shows an arrangement where the heat exchanger is mounted in a ceiling void;

Figures 10a, b and c show three examples of arrangements for the flow of carbon dioxide to a plurality of heat exchanger coils;

Figures 11a, b and c show a further alternative cooling unit arrangement to that of Figures 6a b and c

Figures 12a and b show a cooling arrangement for cooling an array of computer equipment; and

Figures 13a to d show a further cooling arrangement for cooling an array of computer equipment.

Figure 1 shows schematically the general operation of a primary-only cooling system and in particular shows fluid flow around a heat transfer circuit 20. The heat transfer circuit comprises a condenser 30, which is cooled by any appropriate method, a pump 32, which circulates fluid, an expansion device 34 which reduces the heat transfer fluid to a design evaporating pressure and a heat exchanger 36, and a fan or fans 38 contained in a workstation cooling unit 12, which provides cooling to the equipment 10 at the workstation as described in more detail below. The circulating fluid picks up heat from its surroundings in the heat exchanger and returns to the condenser 30, thereby completing the circuit. Instead of a pump 32, the circuit may be gravity fed.

Figure 2 shows schematically the general operation of a secondary cooling system and in particular shows fluid flow around a primary heat transfer circuit 18 and a secondary heat transfer circuit 20. The primary heat transfer circuit 18 comprises a compressor 22, a primary condenser 24, an primary expansion device 26 and an evaporator 28. The heat transfer fluid used in the primary circuit is a volatile primary refrigerant of conventional composition. For example chilled water, refrigerant (for example ammonia) or other cooling medium may be used as the primary refrigerant.

The secondary heat transfer circuit 20 comprises a secondary condenser 30, which is cooled by the evaporator 28, a pump 32, which circulates fluid, a secondary expansion device 34 which reduces the heat transfer fluid to a design evaporating pressure and a heat exchanger 36, and optionally a fan or fans 38 contained in a workstation cooling unit 12, which provides cooling to the equipment 10 at the workstation as described in more detail below. The circulating fluid picks up heat from its surroundings in the heat exchanger and returns to the secondary condenser 30, thereby completing the circuit. Instead of a pump 32, the secondary circuit may be gravity fed.

In this example, the heat transfer fluid circulating in the heat transfer circuit 20 is carbon dioxide under pressure. The advantages of using carbon dioxide are that it is readily available, inexpensive, and relatively non-toxic and non-polluting. Most importantly, however, when compared to systems which use non-volatile secondary heat transfer liquids, such as air, the mass flow of carbon dioxide required to produce the same cooling effect is substantially lower due to the high latent heat of carbon dioxide, when compared to the relatively low specific heat capacities of conventional non-volatile cooling media such as air.

The carbon dioxide arrives at the heat exchanger in a volatile state at temperatures suitable to cool a surface area sufficiently below the local temperature to ensure that heat exchange takes place. Preferably the temperature is in the region of 14°C in order to avoid condensation on the pipes and coil, in an environment having a temperature of 20°C dry bulb, with a relative humidity of 45 to 55% (a typical office environment). In some applications, it is desirable to avoid such condensation because of the risk that water will drip, for example in the vicinity of electrical equipment.

Advantages of carbon dioxide as the volatile fluid are that it is readily available, inexpensive, relatively non-toxic and non-polluting. An important property of carbon dioxide is that compared with non-volatile media such as air and water, the mass flow rate of carbon dioxide required to produce the same cooling effect is substantially lower due to the high latent heat of carbon dioxide when compared with the relatively low specific heat capacities of non-volatile media.

In preferred examples, the working pressure of the system is in the region of 50 Bar, although it may be higher or lower depending on the design of the system and the cooling capacity required.

The use of carbon dioxide as a secondary coolant fluid is known, being described in UK Patent No. 2 258 298. However, it has not been previously considered suitable for providing local cooling of IT workstations where air cooling has dominated ever since the field begun, as it is both electrically benign and intrinsically safe. Carbon dioxide is electrically benign but is not intrinsically safe. Carbon dioxide can present a health and safety issue, if adequate precautions are not taken. Whilst the quantities of carbon dioxide are small in the arrangements described, it is volatile, used at high pressure, and often in confined or small spaces. The main hazards associated with the use of carbon dioxide at high pressure are: (a) its asphyxiation properties; and (b) the very low local temperature associated with the escaped fluid (which may affect people or equipment in the vicinity).

Also, the monitoring of degradation or failure of cooling systems is, in some cases, important for averting damage to the equipment due to over-heating, in the event of a local failure in a cooling system and implementing strategies for maintaining operations and recovery actions. The apparatus may, for example include gas detection device similar to that described in co-pending UK Patent Application No. 0515399.4, for detecting leakages. As it is generally used at high pressures for effective cooling (50 Bar or above) leakage could be a problem. The cooling media system incorporates leak detection and shut-off life safety measures, along with a rejection system to deal safely with any leaked substance.

The cooling unit may be arranged under or above a workstation, for example below the floor (within a raised floor construction or within a floor void) or above the ceiling, for example within a ceiling void.

Figure 3 is a perspective view of features of a workstation 40. The workstation shown comprises two desk work surfaces 42, 44 and two foot wells 46, 48 such that a worker can sit at each of the work surfaces 42, 44 facing each other. Between the foot wells 46, 48 is a computer equipment compartment 50 having front and back walls 52, 54 facing the foot wells 46, 48 and side walls 56, 58. The front, back and side walls define a compartment for the computer equipment. The walls may be insulated as described in further detail below.

Figure 4 shows a schematic cross-sectional view of a workstation of a type illustrated in Figure 3. In the compartment is mounted a personal computer 60. A workstation cooling unit 12 is mounted above the personal computer 60 at the top of the compartment under the work surfaces 42, 44.

As shown schematically in Figure 4, the workstation cooling unit comprises a heat exchanger 36 and a fan arrangement 38 which here is shown including one fan, but could include several fans. When in use, the computer 60 emits heat which is generally contained in the compartment 50. Pipes (not shown in Figure 4) supply CO_2 to and from the heat exchanger 36. The cooling unit 12 includes an air inlet 62 and air outlet 64 and the fan arrangement 38 acts to draw air across the heat exchanger 36 and the cold CO_2 acts to remove heat from the compartment 50. In this arrangement, air circulates within the compartment.

Figure 5 shows an alternative arrangement of the workstation cooling unit 12. Equivalent components are given the same reference numbers as in Figure 4. In this arrangement, the cooling unit 12 is mounted such that it extends from the computer equipment compartment 50 through the work surfaces to above the desk. Again, inlet and outlet pipes 66 pass through the chamber 50 from under the floor to the cooling unit 12 and provide carbon dioxide to the heat exchanger 36. In this arrangement the fans 38 are arranged to draw air from the compartment 50, through the air inlets 62, over the heat exchanger 36 and upwards through the air outlet 64. (Alternatively the fan is arranged to blow air downwards through the compartment towards the floor.) It is envisaged that the air outlet 64 could be connected to an air duct to transport the air away from the workstation, but in this example shown, the air is emitted into the space above the desk work surfaces 42, 44. The air outlet 64 in this arrangement is located approximately 80 mm above the work surfaces.

In some arrangements, for example in view of the air discharge characteristics of the computer equipment, the cooling unit 12 may comprise air flow extract ducts. Such ducts will be associated with an air inlet 62 of the unit and/or air outlet of the computer equipment and assist the hot air exiting the equipment to be directed towards the cooling unit. The duct design will depend on the arrangement of the computer air outlets. For some arrangements, specific ducts can be designed for specific equipment. However, preferably the design of the duct enables its dimensions to be alterable. For example, the duct may be able to extend from the vicinity of the air outlet of the computer equipment towards the cooling unit. The duct or snorkel may be constructed from a rigid material, or it may comprise flexible material, for example in the form of a hose, in which case the snorkel might be able to be manipulated to direct it towards the air outlet of the computer equipment. The snorkel may be of a fixed length, or it may be extendable, for example it may be telescopic. One end of the snorkel may be attachable to the cooling unit in the vicinity of the air inlet; the other end may be positioned in the region of the air outlet of the computer equipment.

The extracted air may be drawn from the cooling unit using fans, either a single unit per snorkel or multiples thereof to provide a back-up unit and/or build redundancy into the fan system. Multiple fans may be installed either in series or in parallel. Parallel fan assemblies may incorporate non-return valves to avoid short circuiting between fan units. The air may be either sucked or blown across the heat exchanger what is supplied with liquid carbon dioxide.

In preferred arrangements, the pressure of CO_2 is 50 Bar which provides a circulating temperature of 14 degrees C. Some arrangements enable loads of up to 5kW per workstation to be dealt with. It is also found that the air emitted at the air outlet 64 in this arrangement is close to room temperature. This can be achieved by, for example choosing an appropriate carbon dioxide flow rate and/or pressure. In some arrangements there may be benefit in providing a temperature sensor for determining the temperature of the emitted air; the output of this sensor may be used to adjust the flow rate and/or pressure to maintain a desired temperature.

In an alternative example, using the arrangement of Figure 5, air is blown using the fan arrangement 38 into the compartment 50 from above the workstation (ie downwards in the arrangement shown in Figure 5). Grilles (not shown) are provided in the floor at the base of the compartment for the discharge of the air to the local vicinity of the computer equipment beneath the workstation.

In the arrangement of Figure 5, it will be seen that the front and back walls 52, 54 include insulation 68. In this case the insulation comprises closed cell foam, but other materials could be used. Insulation is also provided on the side walls (not shown here). The walls and the insulation extend from the floor to the lower surface of the desk work surface and forms a sealed insulated compartment 50. The heat generated by the computer 60 is therefore substantially retained in this compartment for removal by the cooling unit 12.

The heat transfer capacities of the carbon dioxide can enable a smaller heat exchanger to be used and thus the cooling unit may have a smaller, slimmer construction that might have been possible for a comparable unit using chilled water. Such reduced unit size may be beneficial where the unit is to be used in an office environment where space is of a premium and may normally be congested with wiring and cables.

In some arrangements, several units may be provided together. For example, a continuous run of cooling units 12 may be mounted side-by-side. Where the unit is provided as a continuous run made up of sections, each section may be, for example 5 metres long, although longer or shorter sections could be used, as appropriate.

The unit may comprise a gas detection monitoring chamber. By monitoring for gas in the chamber, the presence of carbon dioxide can be detected and thus the integrity of the heat exchanger can be monitored. An automatic shut off safety device can be provided for isolating the supply of carbon dioxide to the unit. A notification device may alert the user to any problem with the gas flow.

The cooling unit may incorporate a connection chamber where connections may be made to the carbon dioxide flow and return distribution pipe work. The chamber may incorporate some or all of the control valves and gas detection monitoring equipment. By providing the gas detection monitoring equipment, leaks associated with carbon dioxide pipe work connections and/or control valves can be efficiently detected.

Gas detection monitoring equipment is described in our co-pending UK Patent Application No. 0515399.4, the contents of which are incorporated herein by reference.

It will be seen that gas detection monitoring equipment similar to that described therein could be incorporated into any of the examples of cooling equipment described herein.

Figures 6a, b and c show a further workstation arrangement. Figure 6a shows a sectional side view of a desk including computer equipment 360 and an associated cooling unit. In this example, part of the cooling unit is mounted under a raised floor 340. The workstation comprises a desk including two work surfaces 342 and 344. Here the desk comprises a back-to-back arrangement for two users and a compartment is arranged under the desk to house computer equipment 360 for both desks. However, a similar arrangement could be used for a single desk.

The compartment comprises a roof 371 and walls 354, 356 shown. The walls comprise heat load screens which extend downwards from the roof 371 to a position above the floor 340. The gap between the walls and the floor provides a ventilation gap. In the raised floor 340 within the compartment are provided air grilles 370 providing ventilation between the compartment and the under floor cavity 362.

The computer equipment 360 stands on the raised floor and in the floor cavity 362 under the raised floor is mounted a heat exchanger 336 which includes a coil for carbon dioxide. This arrangement is shown in more detail in the plan view of Figure 6b.

At the air outlet 372 of the computer equipment 360 is arranged a snorkel device 374 which contains a fan (or fans) 376. The snorkel device 374 extends from the air outlet 372 to an inlet hole 380 in the floor grille 370. When the fan is activated, air is drawn from the air outlet 372 of the computer 360, through the snorkel device 374 (past the fan 376), through the inlet hole 380 into the floor cavity 362 where is passes over the heat exchanger 336 and then exits the floor cavity through the grille 370. The snorkel device shown could be adapted to have several inlets to collect air from several outlet locations on the equipment.

Figure 6c shows a rear view of the snorkel device 374 and computer 360 arrangement.

As can be seen in Figure 6b, the heat exchanger 336 extends under several workstations to provide cooling for several items of computer equipment. In this arrangement there may be two or more items of computer equipment under each desk; the heat exchanger 336 provides cooling to both of these items. Furthermore, where several workstations are located together, the heat exchanger can extend across several workstations, providing cooling to several workstations.

A manifold chamber 390 is provided at the end of each coil and includes a gas detection device similar to that described in UK Patent Application No. 0515399.4,

Any of the examples which show integral fans could, alternatively or additionally, be connected to workstations through a ducted air system.

Figure 7 shows an alternative heat exchanger unit 410 arrangement in which the heat exchanger coil 400 is arranged at floor level (compared with under the floor as in the arrangement of Figure 6a).

The heat exchanger unit 410 is formed so as to be a similar size as a standard floor tile 412 so that it can easily be mounted within the floor on the floor pedestals 414. The heat exchanger unit comprises a base 416, side walls 418, and a roof comprising a central solid portion 420 and two parallel grille sections 422 extending along two sides of the roof of the unit. The heat exchanger is mounted within the unit, under the solid portion 420. Carbon dioxide is provided to the coil by flow and return pipes provided within the floor void 426. Carbon dioxide supply pipes 428 are provided with a steel cover 430 for protection against damage.

The heat exchanger comprises a plane coil which is mounted having its plane at an angle to the base of the unit. In this way, when the unit is mounted under the workstation the snorkel and fan arrangement is arranged to blow warm air from the equipment into the unit through one of the grilles 422, over the tilted coil and out through the other grille 422. In this way, the warm air from the equipment may be cooled.

Figure 8 shows a further example of a heat exchanger unit. This arrangement is similar to that of Figure 7; like parts are indicated by like numerals. In the arrangement of Figure 8, however, the carbon dioxide supply pipes 428 are arranged immediately beneath the base 416 of the unit 410. Thus the carbon dioxide supply pipes 424 are shorter and the workings of the unit do not extend so far into the floor void 426. This is of benefit in that there is less potential interference with services already present in the floor void, for example cables. It will be seen, however, that the height of the unit of Figure 8 is greater than that of Figure 7; there may be some applications where the arrangement of Figure 7 is preferred.

Also in the arrangement of Figure 8, an inlet 432 specifically for the entry of air from a snorkel device (see for example Figure 6a) is provided in one of the grilles. The flow of air through the unit is shown by arrows.

Figure 9 shows an arrangement where the heat exchanger is mounted in a ceiling void. In this arrangement, the floor may still comprise a false floor 612 mounted on floor pedestals 614, but in this arrangement the floor void may be left clear of the cooling apparatus to allow more space for, for example, cables.

In this arrangement, the computer equipment 660 is located under a desk 600 at the workstation 610. A duct 612 extends from adjacent the computer equipment 660 under the desk 600, through the desk top 614 and upwards to the ceiling 615. An inlet formation 618 is provided at the lower end of the duct 612 for directing air from an outlet or outlets of the computer equipment 660 to the duct 612.

The ceiling 615 comprises a false ceiling 616 below a ceiling void 620. Within the ceiling void 620 is mounted a heat exchanger coil 622. Flow and return pipes 624, 625 provide carbon dioxide to the coil 622 in a manner similar to that described above. The duct extends upwards through the false ceiling 616 to the coil 622. A fan arrangement 626 is provided at the top of the duct 612 adjacent the coil 622. The fan arrangement 626 is arranged to draw warm air upwards from the computer equipment 660, through the duct 612 and over the coil 622 and into the ceiling void 620. The air is cooled as it passes over the coil 622.

Figures 10a, 10b and 10c show three different arrangements for the supply of carbon dioxide to and from a plurality of heat exchanger coils.

In the arrangements of Figures 10a, 10b and 10c, carbon dioxide flow and return pipes 700, 702 supply carbon dioxide to a plurality of heat exchange coils 710. Valves 720 and 721 are provided to control the flow of carbon dioxide in the system. In the arrangement of Figure 10a, the valve locations allow dual coil units to be arranged in parallel; this allows additional coils to be arranged in series. Figure 10b and 10c show alternative arrangements.

Figure 11a shows a further alternative cooling unit arrangement to that of Figure 6a. In the arrangement of Figure 11, the snorkel or duct 374' comprises a flexible hose 500 extending from an inlet formation 502 for enclosing an outlet region 504 of the equipment, to the fan arrangement 376.

A cable path enclosure 506 is arranged under the workstation above the coil and is adapted to receive cables from the equipment, cooling unit and/or other cables. A drain point 508 may be provided beneath the heat exchanger, for the removal of any water which condenses on the coil.

In Figure 11b, it will be seen that, compared with Figure 6b, further inlets 380 have been provided in the grille 370 to allow for different snorkel positions and thus to give flexibility in arrangement of equipment at the workstations, and/or to provide for more than one snorkel or hose arrangement to be provided for each item of equipment, to provide additional cooling.

Figures 12a and 12b show a cooling arrangement for cooling an array of computer equipment.

Figure12a shows a schematic plan view of an array of eight items of computer equipment 800 arranged side-by-side beneath a desk (not shown). The width of the desk may be, for example 1600mm (A); the depth of the desk (B) may be 600 mm.

The cooling arrangement for cooling the computer equipment 800 in the arrangement of Figures 12a and b could for example be similar to that of Figure 6a to c.

With reference to Figure 6c, a coil unit extends under the full array of eight items of computer equipment 800; the computer equipment is mounted between air grilles.

Figure 12b shows a side view of the heat exchanger coil 810 mounted beneath the computer equipment 800 (in this arrangement, the coil is tilted to give more efficient cooling). As in the arrangement shown, for example in Figure 8, warm air from the computer equipment passes through one of the air grilles 820, over the coil 810 and exits through the opposite air grille 840.

Whilst in many cases the air entry and exit are in the same direction for each item of computer equipment, in this arrangement, however, the air inlet and outlet grilles are interchangeable. Thus the arrangement may be such that the direction of air flow may be in either direction across the coil 810. This has the advantage that the computer equipment may be arranged in the most convenient orientation for the user: with the air outlet of the equipment facing grille 820 or grille 840.

Furthermore, as shown in the arrangement of Figures 12a and b, one or more dividing members can be provided so that air flow can be controlled with regard to a particular section of the coil 810.

In the arrangement of Figure 12a, a dividing plate 850 is provided between two of the items of computer equipment. The plate extends substantially vertically through the passage containing the heat exchanger coil 810, and also preferably through the compartment under the desk containing the computer equipment. In the arrangement shown in Figure 12b, the coil passes through the plate 850.

By isolating the air flow on the two sides of the dividing plate 850, the air flow on the two sides can be different. As shown in Figure 12a, the air flow on one side of the dividing plate can be opposite that on the other side. Thus on one side of the plate 850, the grille is an air inlet grille 820 for warm air from equipment E1 to E4, and on the other side, the grille is an air outlet grille 840' for equipment E5 to E8. Similarly, on one side of the plate, the other grille is an air outlet grille 840 or warm air from equipment E1 to E4, and on the other side, the grille provides an air inlet grille 820' for equipment E5 to E8.

Thus the dividing plate allows flow in opposing directions and thus avoid the need for the equipment to be positioned so that it all faces in the same direction. Since the equipment is usually arranged such that it faces its user, the use of the dividing plate allows the system to be more flexible with regard to different desk and workstation layout possibilities.

It will be appreciated that further dividing plates could be used to provide further variations in air flow and thus further flexibility in the arrangement of equipment in relation to the cooling unit.

Figures 13a to d show a further cooling arrangement for cooling an array of computer equipment. Figures 13a and b show, respectively, a perspective and a side sectional view of a workstation 900 including a desk 910 being arranged such that two users can work at the desk 910 facing each other. Under the work surface 912 of the desk is an insulated compartment 914 in which a plurality of items of computer equipment 916 is mounted. The construction of the compartment 914 is similar to that of the example shown in Figure 4, described above. In this arrangement, a double-walled construction is used including heat load screens

From the perspective view of Figure 13a and the plan view of this arrangement shown in Figure 13c it can be seen that the compartment 914 extends across the width of the desk 910 and houses eight items of computer equipment 916A to H.

The structure of the cooling apparatus is similar to that of Figures 6 and 11 except that no air directing formation is mounted within the desk to direct the air. A cooling unit 918 comprising plurality of floor tile-replacement units (600 mm square) is provided beneath the compartment 914. The cooling unit 918 extends across the width of the desk 910 (and, optionally, beyond) and includes an air channel 919 in which are arranged a vertically mounted heat exchanger coil 920 and a fan 922. Carbon dioxide supply pipes 923 supply carbon dioxide to the coil 920. A manifold chamber is provided at the ends of the coils and includes a gas detection device.

The air channel of the cooling unit 918 is in air communication with the inside of the compartment 914 via air inlet and outlet grilles 924, 926. The computer equipment stands on a raised perforated platform 928 mounted on the floor of the compartment 914 and at least partially over the grilles 924, 926 so that air flow to the grilles is not substantially impeded by the computer equipment 916. The raised platform allows air to pass into the underfloor plenum.

With reference to Figure 13a, when the fan is activated, air circulates between the compartment 914 and the air channel 919. Specifically, warm air exiting the air outlet 930 of the computer passes through the compartment 914 to the air inlet grille 924, is drawn through the air channel 919 by the fan 922 and passes over the coil 920 where the air is cooled. The cool air then enters the compartment via the air outlet grille 926. In preferred arrangements, the air inlet of the computer equipment is located close to the air outlet grille 926 so that cool air is drawn into the computer equipment inlet 932.

In this way, effective cooling of the equipment can be achieved. For example, in an arrangement similar to that described, air exiting the outlet 930 may have a temperature of from 30 to 35 degrees C; cooled air entering the compartment 914 might have a temperature of about 15 degrees C. In some arrangements, further fans may be provided in the air channel 919 upstream of the coil 920.

Considering Figure 13c, it will be seen that a dividing plate 932 is provided in the air channel such that opposite flow of air can be achieved in the portion of the compartment cooling equipment 916A to D compared with equipment 916E to H in a manner similar to that of the arrangement of Figure 12. Thus the dividing plate forms two air channels beneath the desk, the coil extending through both.

This arrangement is shown in Figure 13d which shows a simplified perspective view of parts of the cooling unit 918.

From Figures 13c and d it will be seen that a single coil is provided across the array of equipment, and one fan arrangement is provided for each pair of items of computer equipment. It will be appreciated that other arrangements are possible. Further dividing plates may be provided, for example to form further air channels (for example so that only one fan is provided in each channel) and/or to divide the compartment 914 to further direct the air flow.

It will be seen that, in this arrangement, the two users sitting facing each other at the desk can each have a plurality of items of computer equipment facing them, while efficiencies may be made by using a common cooling unit arrangement to effect cooling of all of the equipment at that workstation.

It will be understood that the present invention has been described above purely by way of example, and modification of detail can be made within the scope of the invention.

Each feature disclosed in the description, and (where appropriate) the claims and drawings may be provided independently or in any appropriate combination.

Claims

1. A workstation cooling unit, the unit comprising:

a heat transfer path adapted to contain a heat transfer fluid, the heat transfer path being adapted for connection to a condenser to form a heat transfer circuit, and

a heat exchanger for cooling the workstation.

2. A cooling unit according to claim1, wherein the heat transfer fluid comprises a volatile fluid.

3. Cooling unit according to claim 2, wherein the heat transfer fluid comprises carbon dioxide.

4. A cooling unit according to any preceding claim, wherein the heat exchanger is adapted to be mounted at the workstation.

5. A cooling unit according to claim 4, wherein the heat exchanger is adapted to be mounted at least partly in the workstation.

6. A cooling unit according to any preceding claim, wherein the heat exchanger includes a finned coil.

7. A cooling unit according to any preceding claim further including leak detection apparatus for detecting leak of heat transfer fluid.

8. Cooling unit according to any preceding claim further including a fan adapted to move air over the heat exchanger.

9. Cooling unit according to any preceding claim, wherein the heat exchanger is arranged in an air channel.

10. Cooling unit according to claim 9 wherein a fan is mounted in the air channel.

11. Cooling unit according to claim 9 or claim 10, including a plurality of air channels.

12. Cooling unit according to any preceding claim wherein the heat exchanger is mounted in an air chamber, the apparatus further comprising a dividing member for dividing the air chamber to form a plurality of air channels.

13. Cooling unit according to any of claims 8 to 12, wherein the unit further includes a housing having an air inlet and an air outlet, the fan being arranged for moving air from the inlet to the outlet.

14. A cooling unit according to any preceding claim, wherein the unit further includes an air directing formation.

15. A cooling unit according to claim 14, wherein the air directing formation includes a duct for directing the air.

16. A cooling unit according to claim 15, wherein the duct further includes an inlet formation, wherein the inlet formation is adapted to enclose an outlet of the equipment.

17. A cooling unit according to claim 16, wherein the duct includes a plurality of inlet formations for enclosing a plurality of outlet regions of the equipment.

18. A cooling unit according to any of claims 15 to 17, wherein the duct comprises a flexible hose.

19. A cooling unit according to any of claims 15 to 18, including a fan arranged in the duct.

20. A cooling unit according to any preceding claim, where the heat exchanger is adapted to be mounted beneath the workstation.

21. A cooling unit according to any preceding claim, wherein the heat exchanger is adapted to be mounted at or directly above floor level.

22. A cooling unit according to any preceding claim, further comprising cable management formations.

23. A cooling unit according to any preceding claim, wherein the heat exchanger is adapted to provide cooling for a plurality of workstations.

24. A cooling unit according to any preceding claim, being adapted for use in a secondary heat transfer circuit of a cooling system.

25. A cooling apparatus comprising a cooling unit according to any of claims 1 to 24 and a condenser connected to the heat transfer path to form a secondary heat transfer circuit, the condenser being adapted to be cooled by a primary heat transfer circuit.

26. Workstation cooling system comprising:

a primary heat transfer circuit;

a secondary heat transfer circuit for containing a secondary heat transfer fluid, a secondary condenser adapted to be cooled by the primary heat transfer circuit and a secondary heat exchanger for cooling the workstation.

27. A workstation cooling system according to claim 27, comprising a plurality of cooling units according to any of claims 1 to 24.

28. A cooling unit for cooling a workstation, the unit including an air inlet, an air outlet, an air duct and a heat exchanger for forming part of a secondary heat transfer circuit.

29. A workstation adapted to house a cooling unit according to any of claims 1 to 24.

30. A workstation according to claim 29, further including a compartment for housing the cooling unit such that at least a part of the cooling unit is mounted in the compartment.

31. A workstation according to claim 30, wherein the compartment is adapted to house heat-generating equipment.

32. A workstation according to claim 31, comprising heat-generating equipment, wherein the heat-generating equipment preferably comprises computer equipment.

33. A workstation according to claim 31 or claim 32, wherein the compartment is adapted to be substantially sealed when the cooling unit and equipment are housed in the compartment.

34. A workstation according to any of claims 31 to 33, wherein the compartment comprises heat insulation.

35. A workstation comprising equipment to be cooled and a cooling unit for cooling the equipment, the unit comprising:

a heat transfer path adapted to contain a heat transfer fluid, the heat transfer path being adapted for connection to a condenser to form a heat transfer circuit, and

a heat exchanger for cooling the equipment.

36. A workstation according to claim 35, wherein the heat transfer fluid is a volatile fluid, preferably carbon dioxide.

37. A workstation according to claim 35 or claim 36 wherein the heat exchanger is mounted beneath the equipment.

38. A workstation according to any of claims 29 to 37, wherein the equipment comprises computer equipment.

39. A floor unit for mounting beneath a workstation area, the floor unit comprising a heat transfer path adapted to contain a heat transfer fluid, the heat transfer path being adapted for connection to a condenser to form a heat transfer circuit, and

a heat exchanger for cooling the workstation area.

40. Use of a volatile fluid at a heat transfer fluid in an apparatus for cooling a workstation.

41. Use according to claim 40, wherein the heat transfer fluid comprises carbon dioxide.

42. A method of cooling a workstation, the method comprising:

circulating fluid through a heat transfer circuit to a heat exchanger disposed adjacent or in the workstation.

43. A method of cooling a workstation, the method comprising:

circulating fluid through a heat transfer circuit to a heat exchanger disposed such that the heat exchanger effects removal of heat from the workstation.

44. A method according to claim 42 or claim 43, wherein the fluid comprises a volatile fluid, preferably carbon dioxide.

45. A method according to any of claims 42 to 44, wherein the heat transfer circuit comprises a secondary heat transfer circuit comprising a secondary condenser, and the method further comprises circulating fluid through a primary heat transfer circuit to effect cooling at the secondary condenser.

46. A cooling unit being substantially as herein described having reference to any one or more of the accompanying drawings.

47. Cooling apparatus or cooling system being substantially as herein described having reference to any one or more of the accompanying drawings.

48. A workstation being substantially as herein described having reference to any one or more of the accompanying drawings.

49. A cooling method, optionally for cooling a workstation or computer equipment, the method being substantially as herein described.

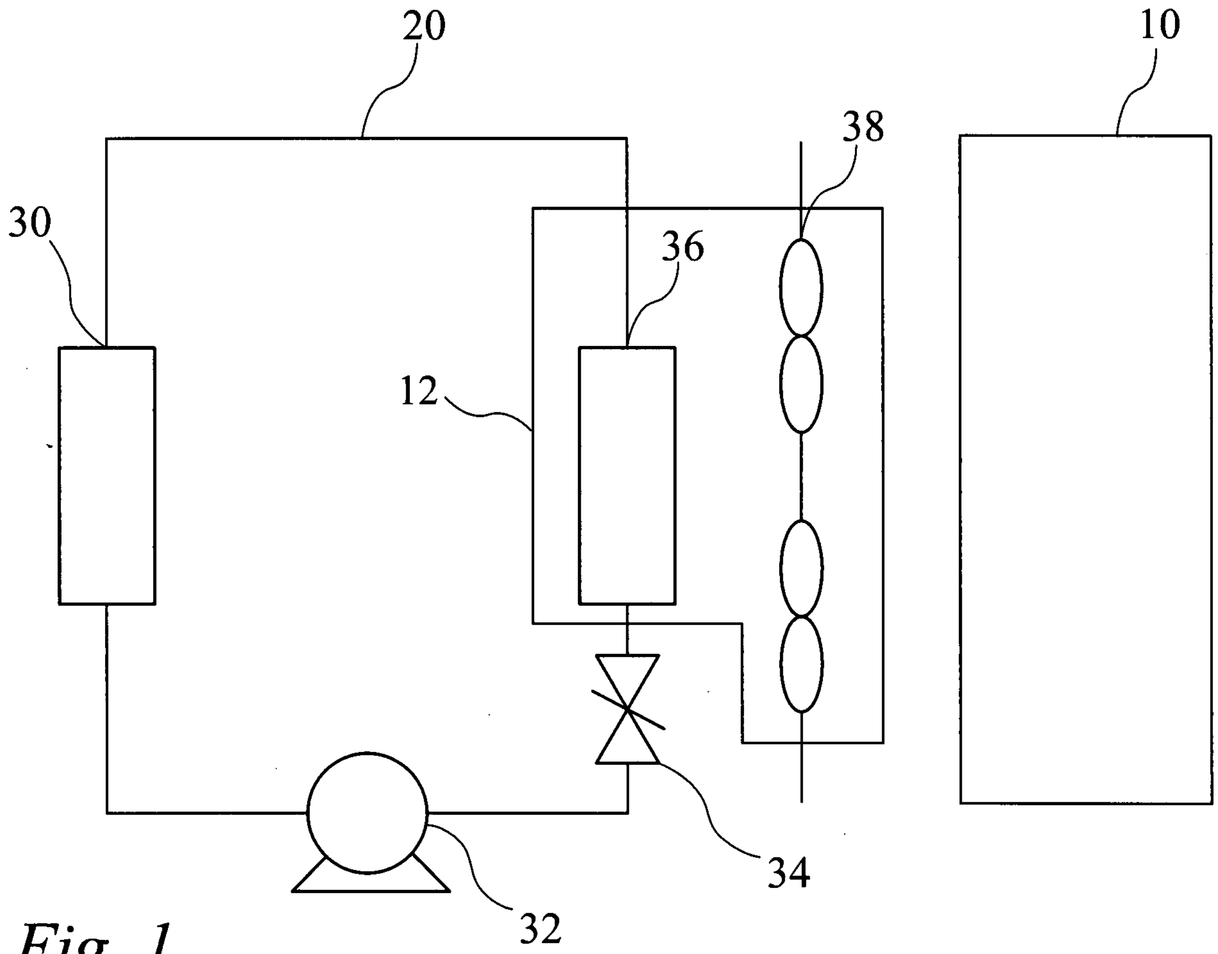

Fig. 1

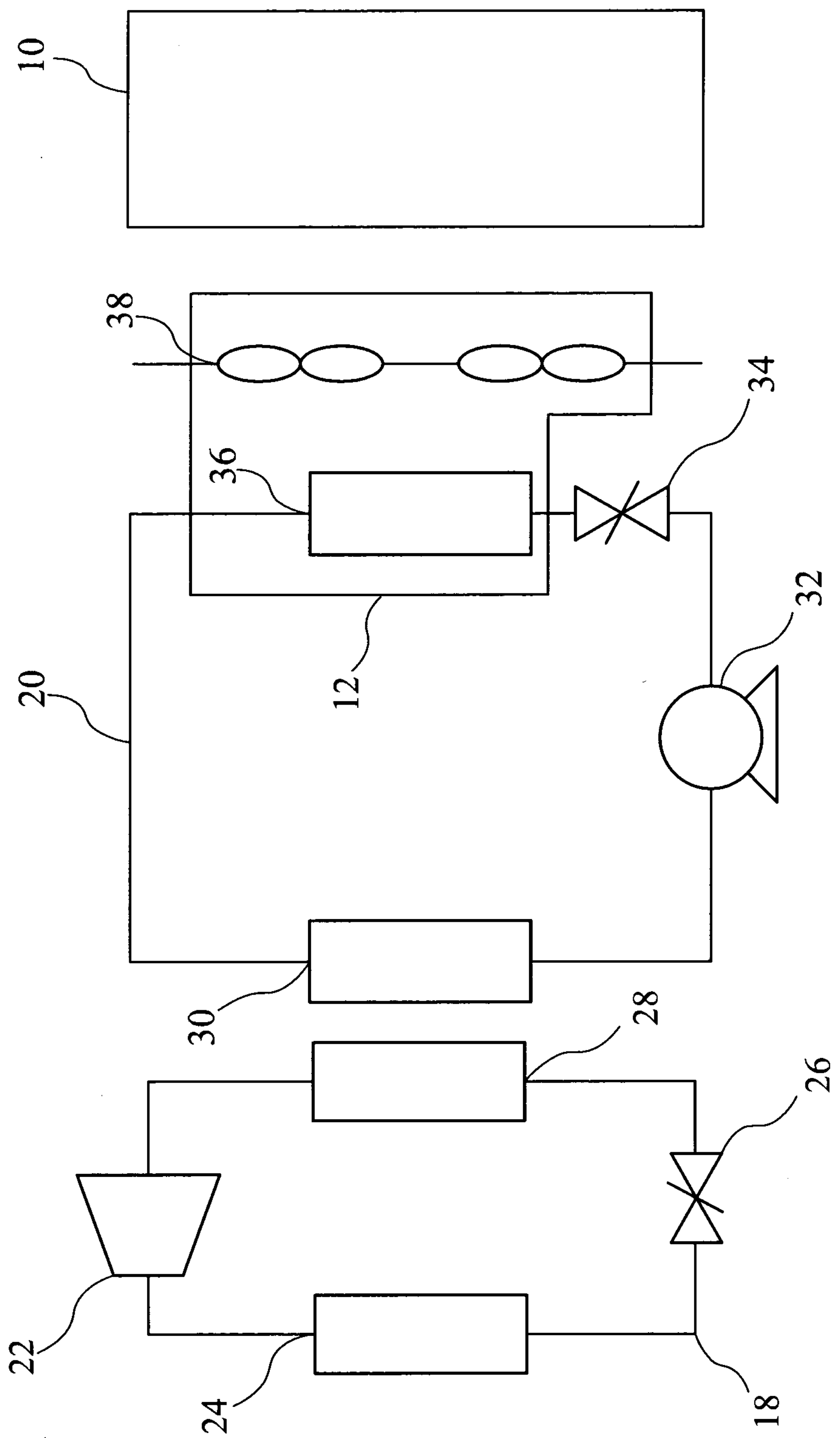

Fig. 2

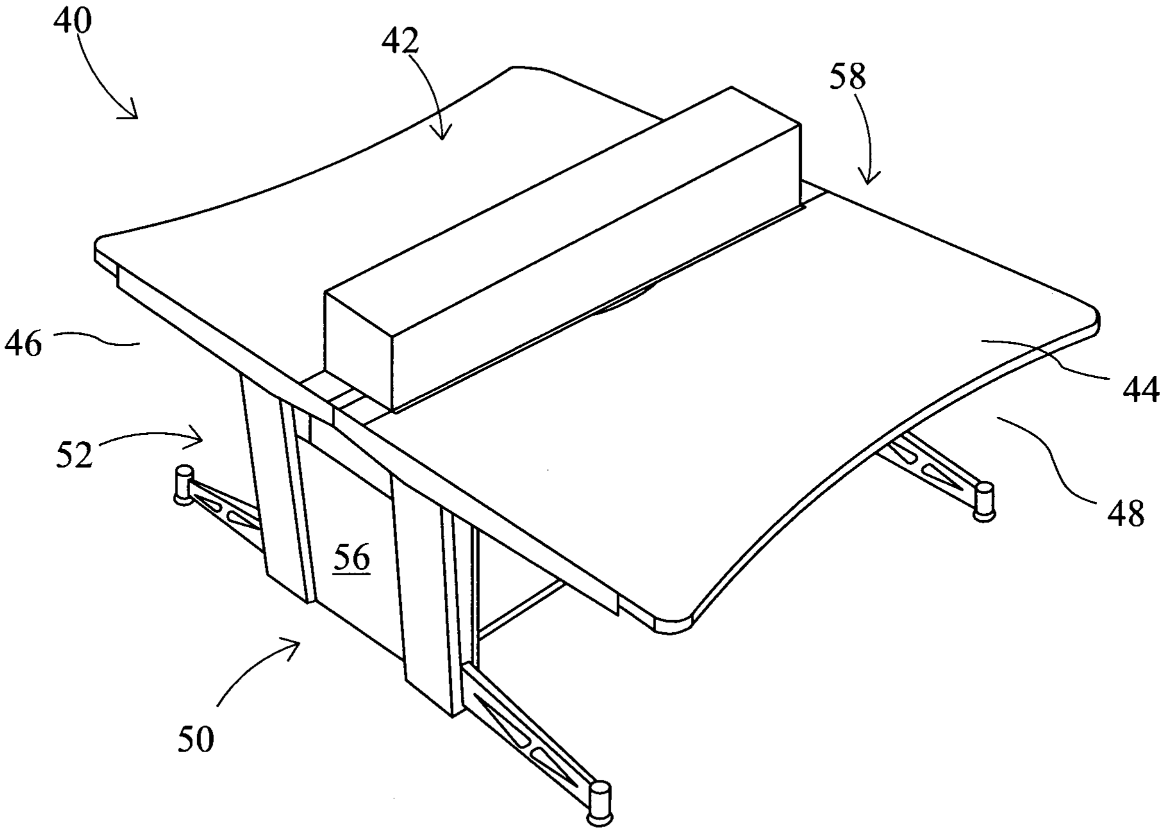

Fig. 3

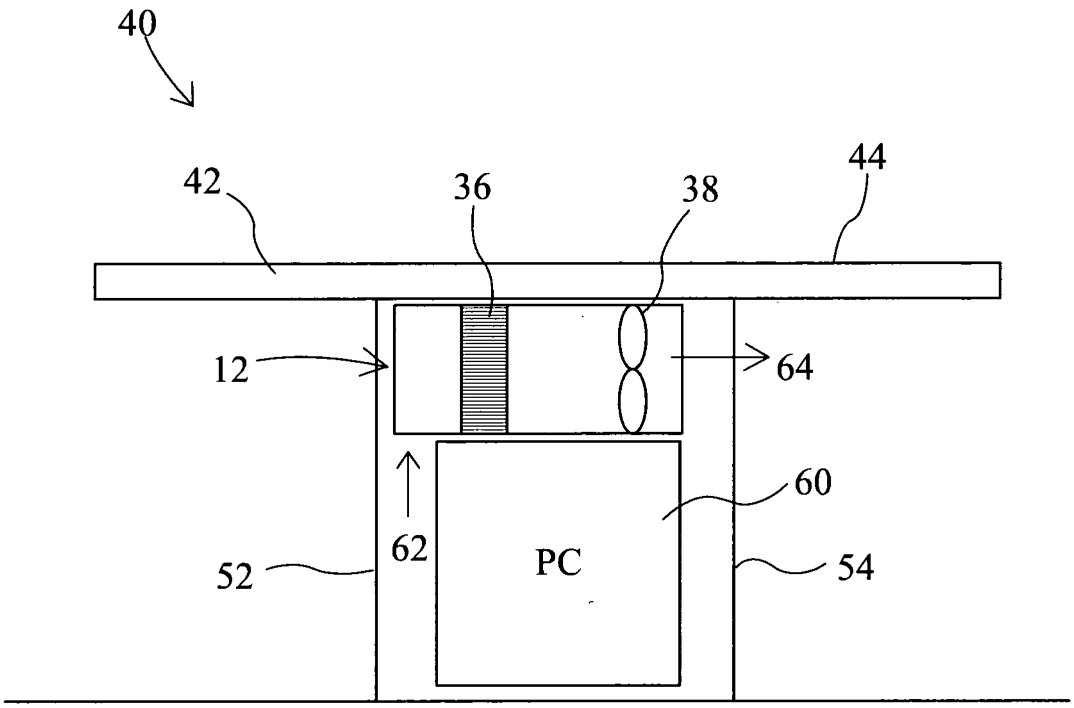

Fig. 4

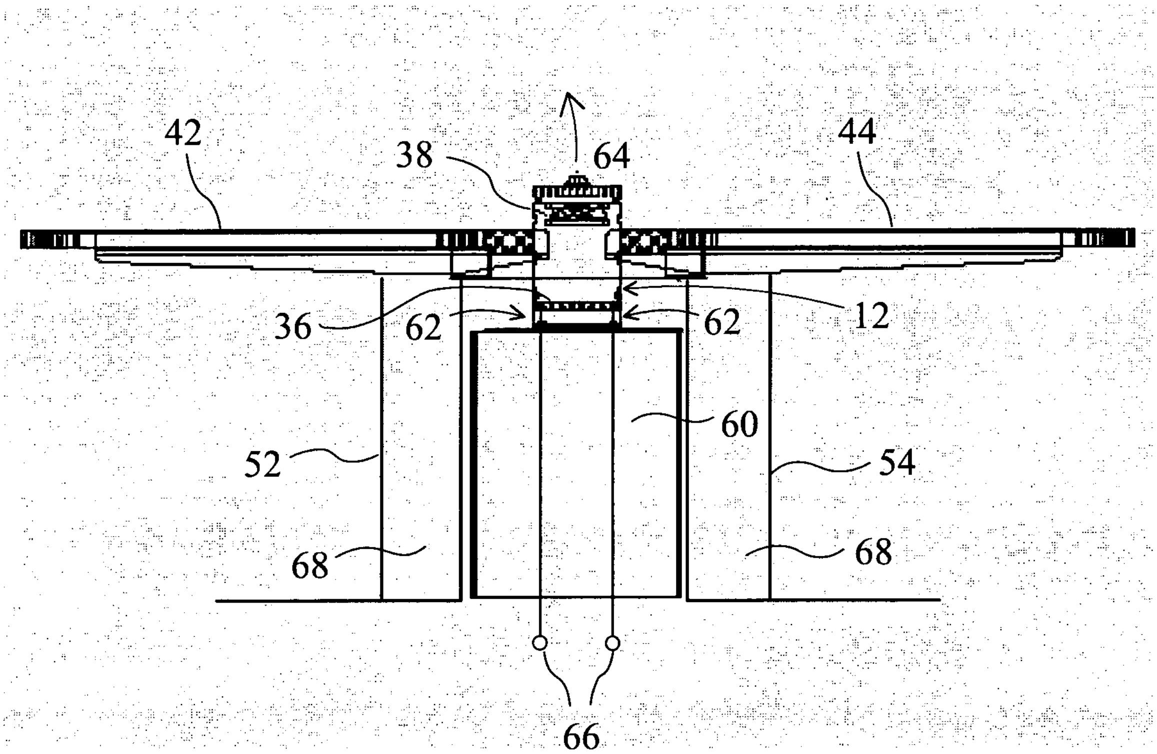

Fig. 5

Fig. 6a

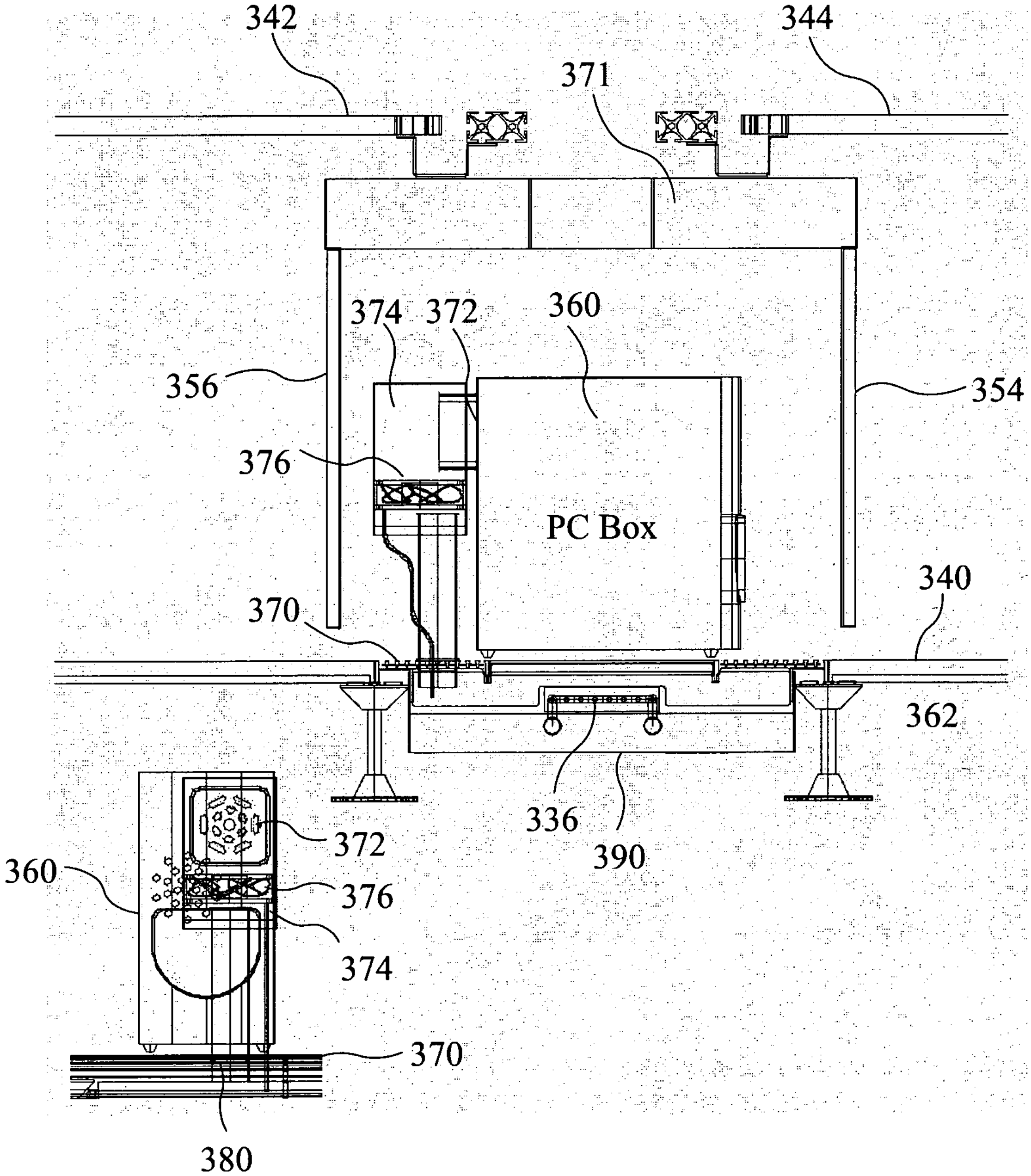
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Fig. 6c

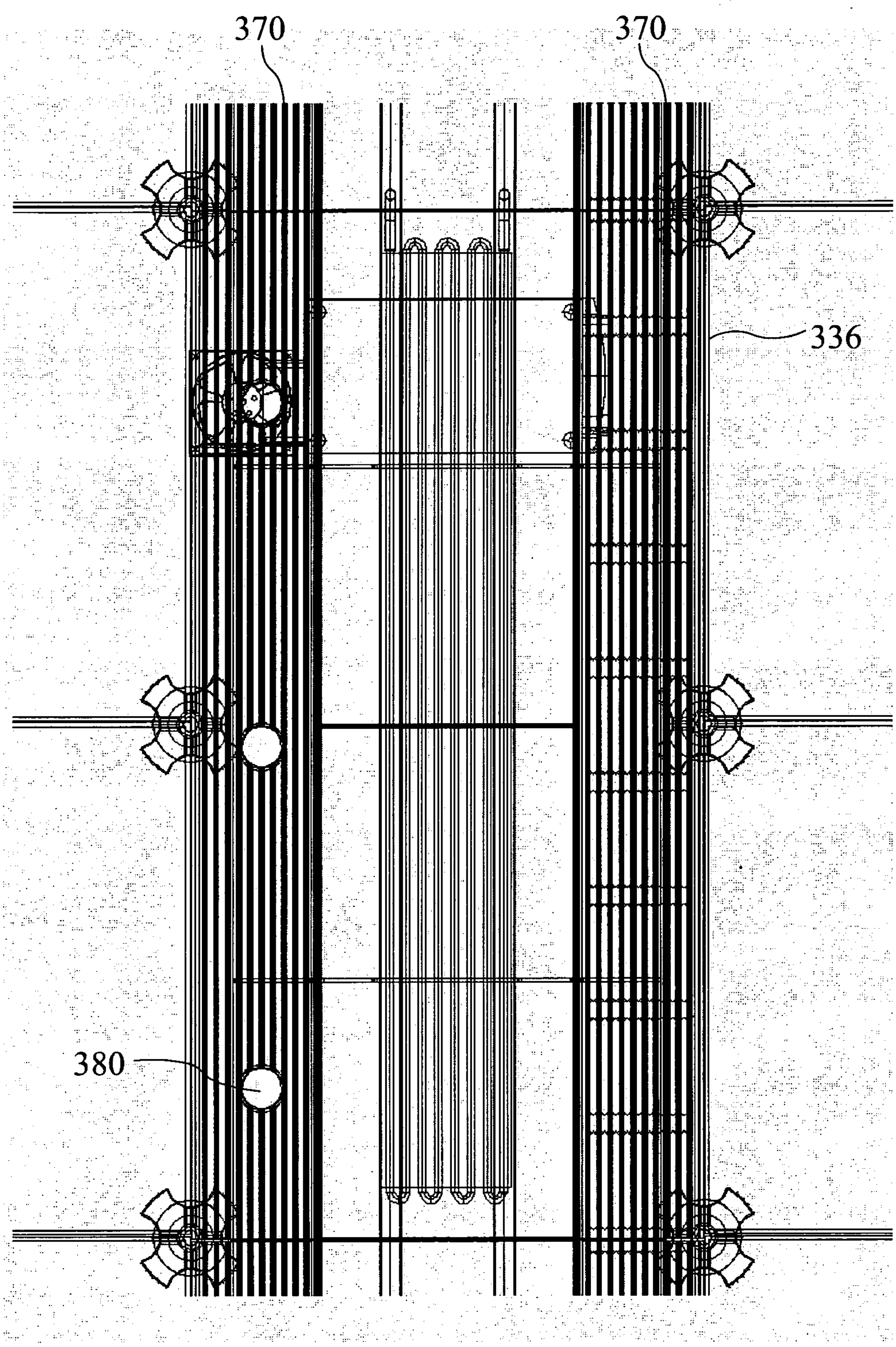


Fig. 6b

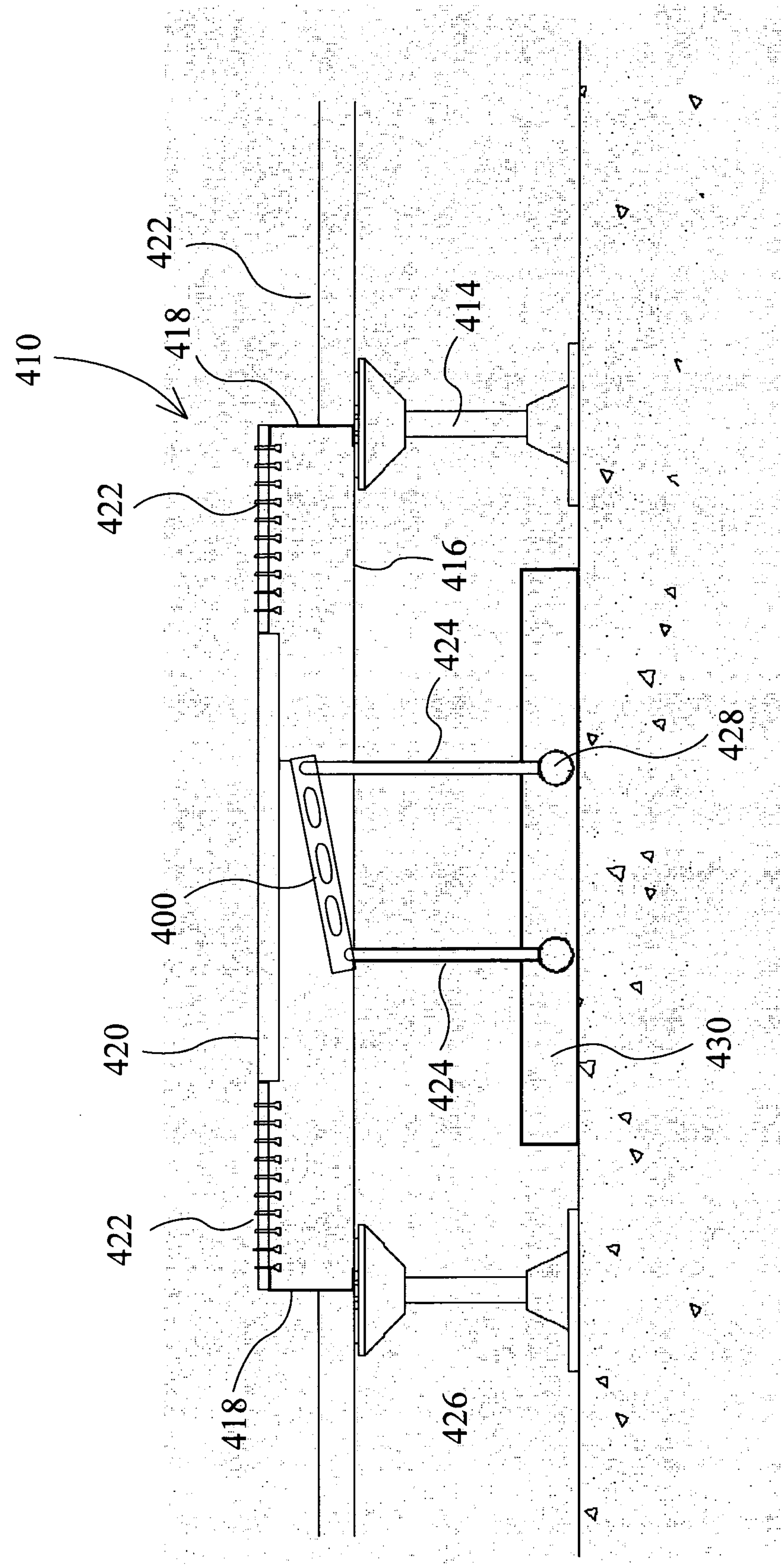
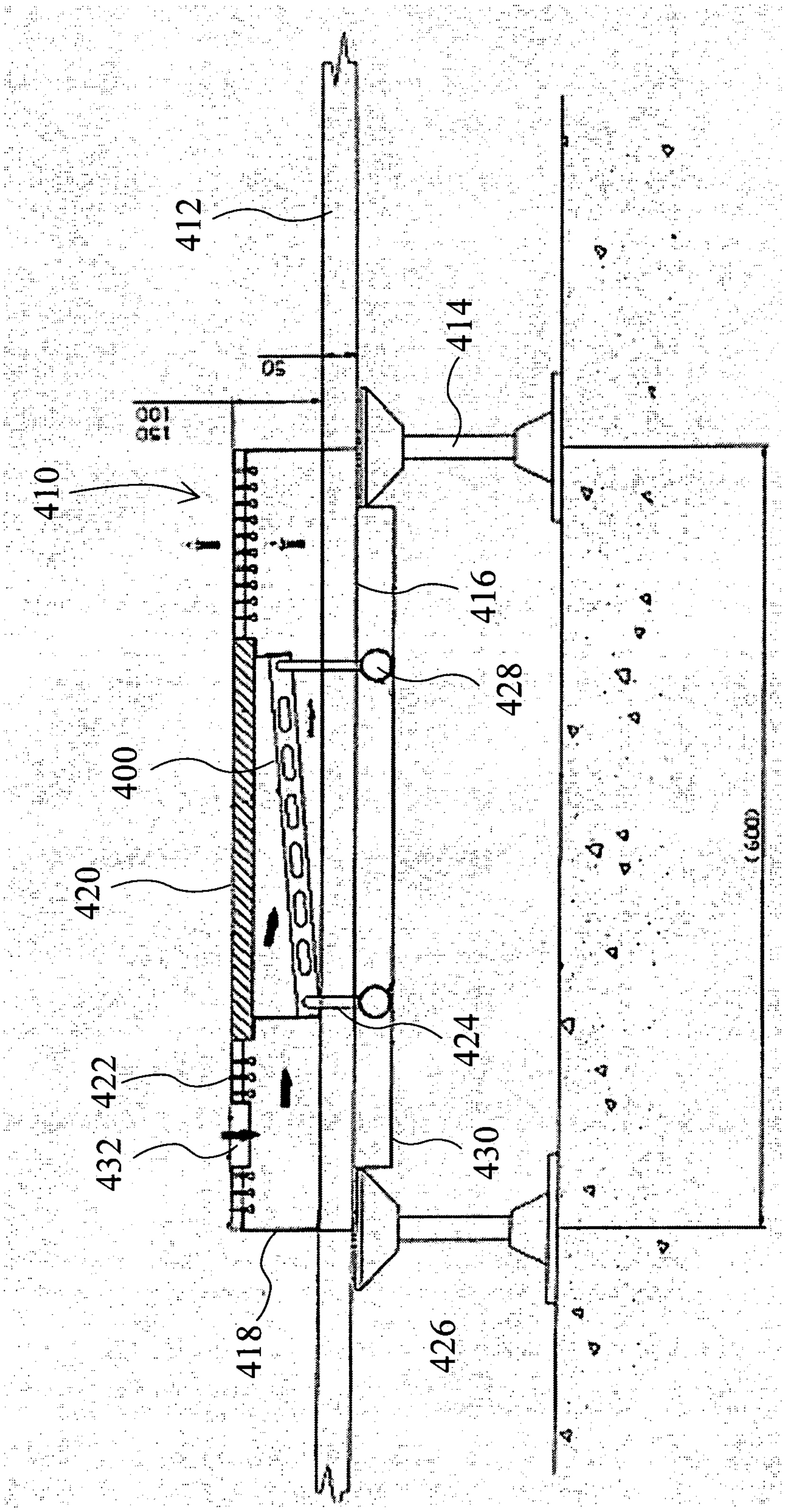


Fig. 7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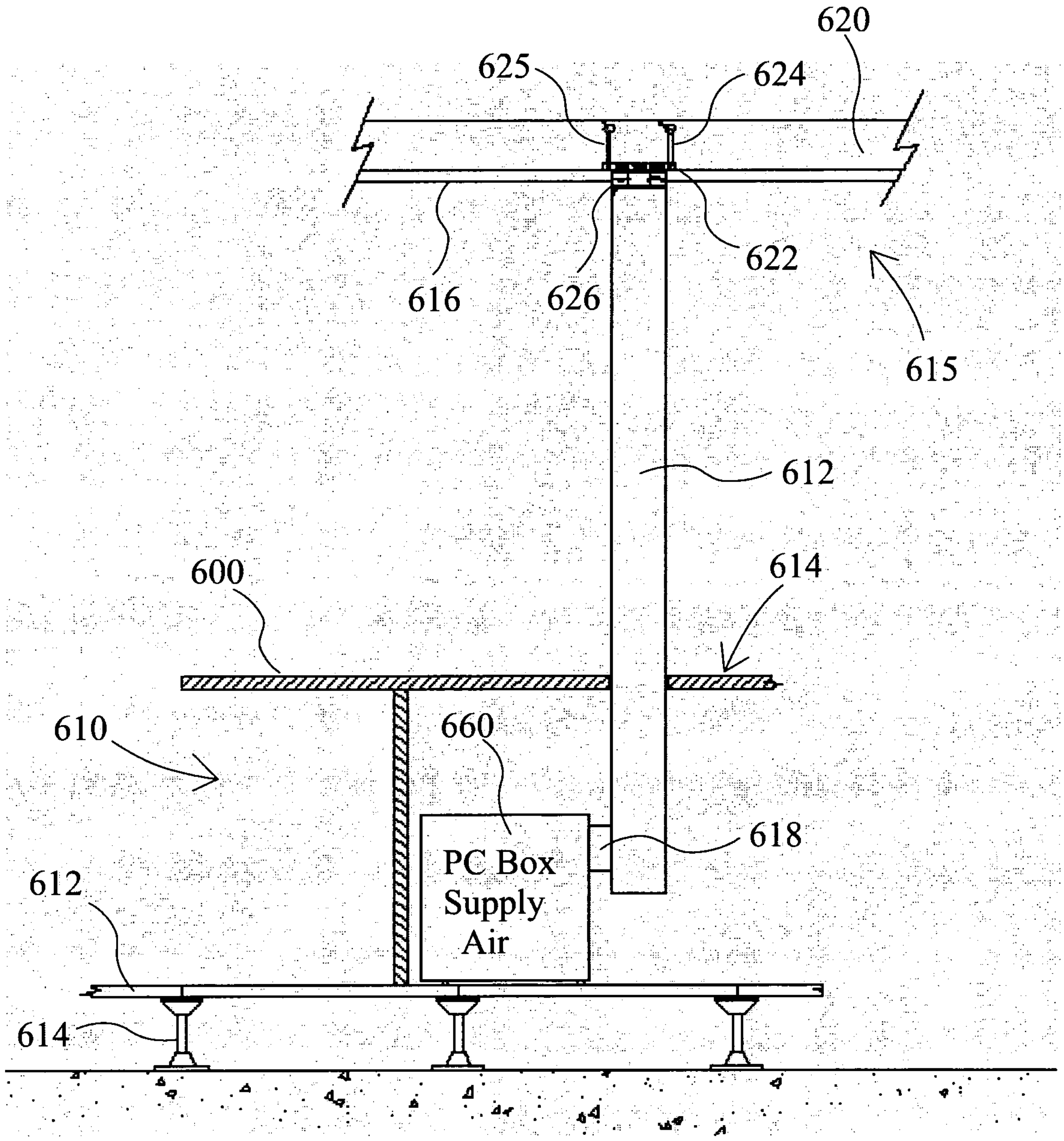
(600)

Fig. 8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PC Box
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614

Fig. 9

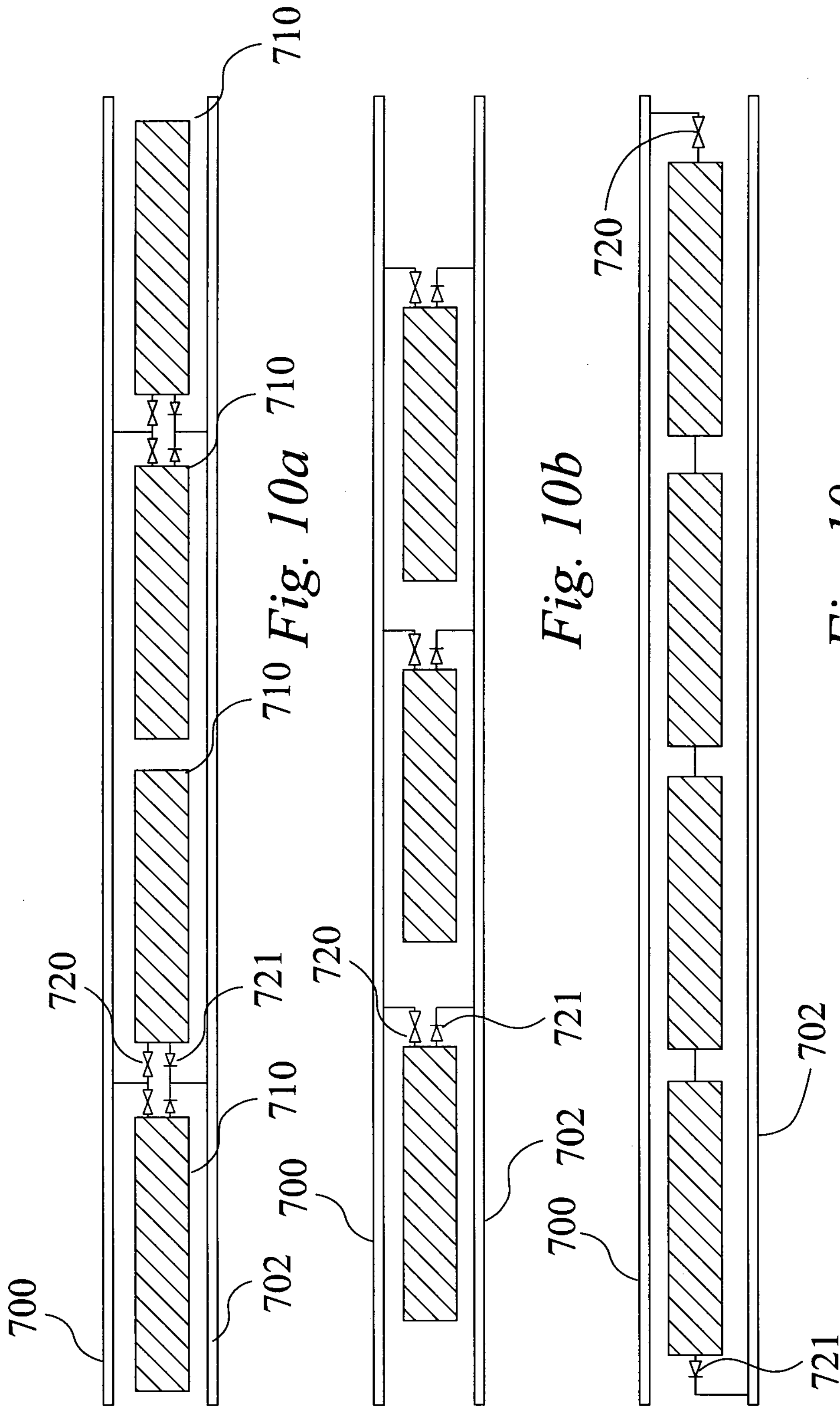


Fig. 10a

Fig. 10b

Fig. 10c

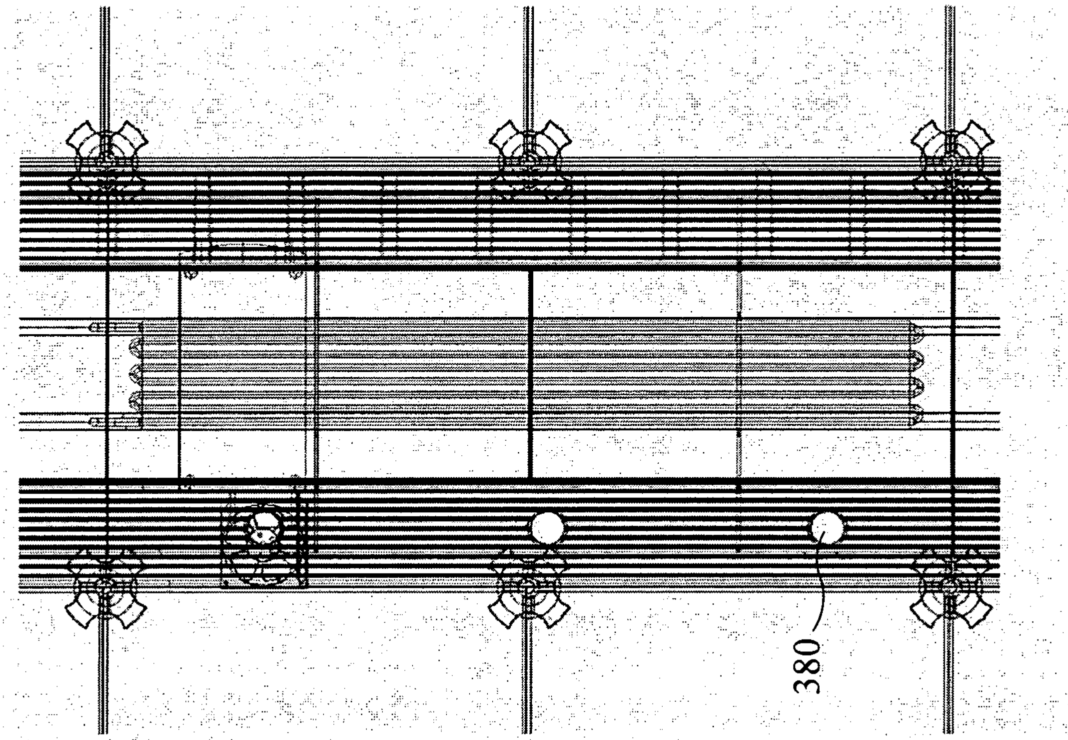


Fig. 11b

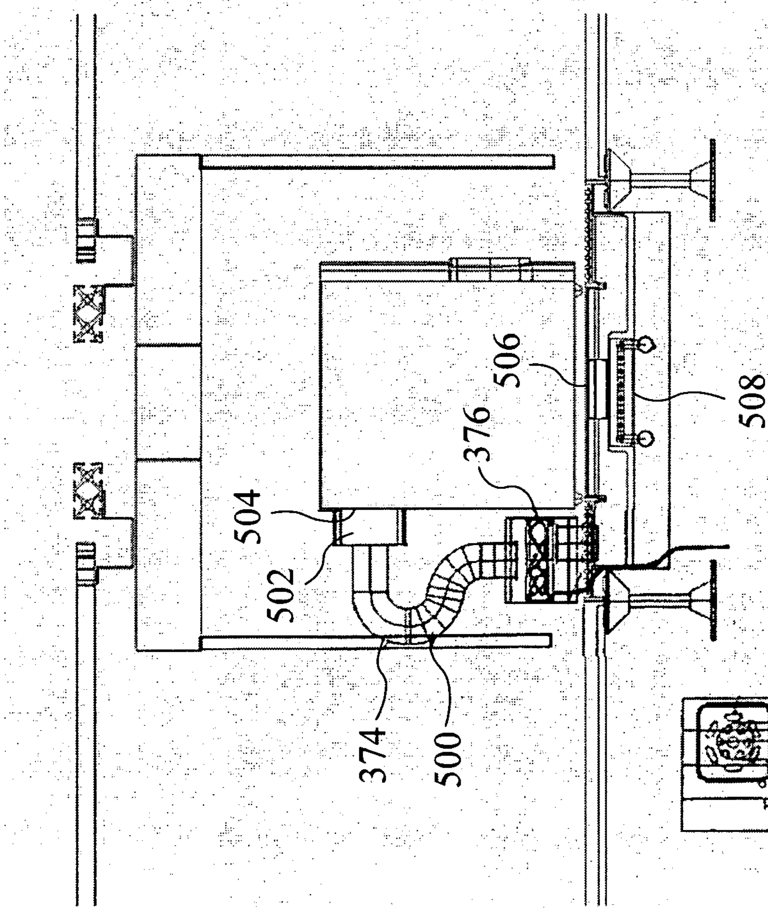


Fig. 11a

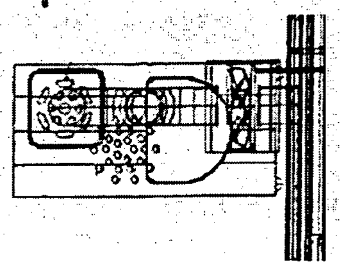


Fig. 11c

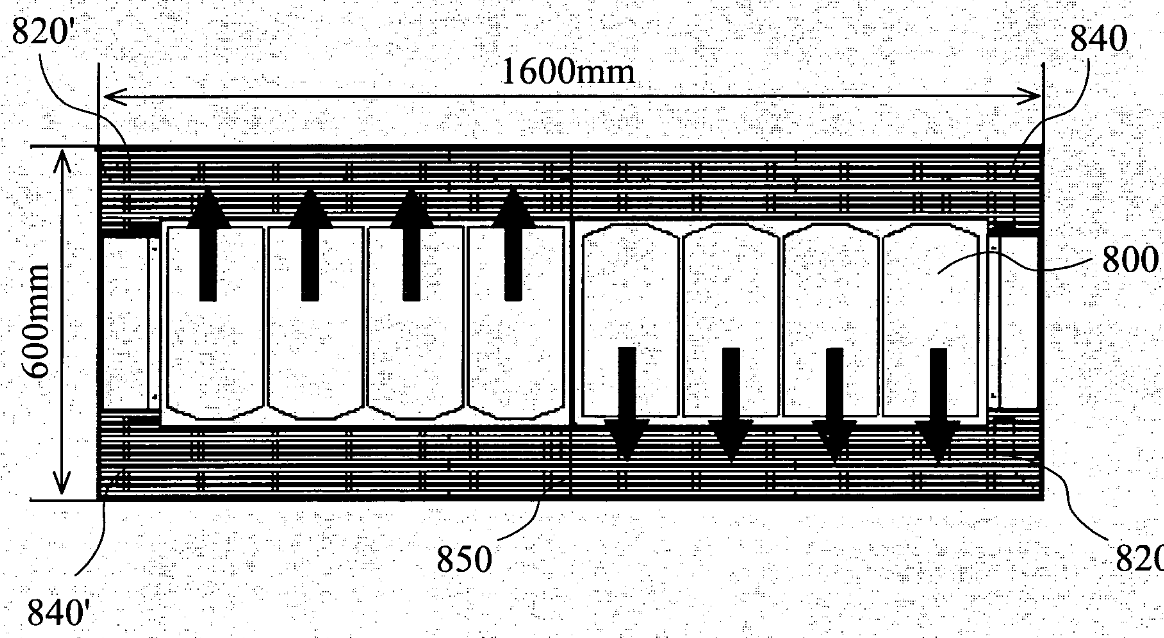


Fig. 12a

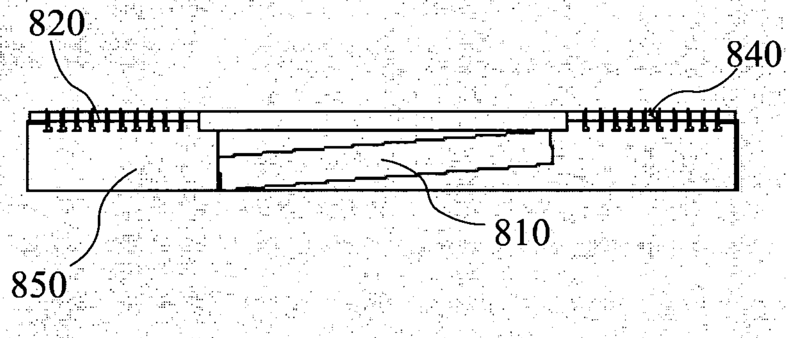


Fig. 12b

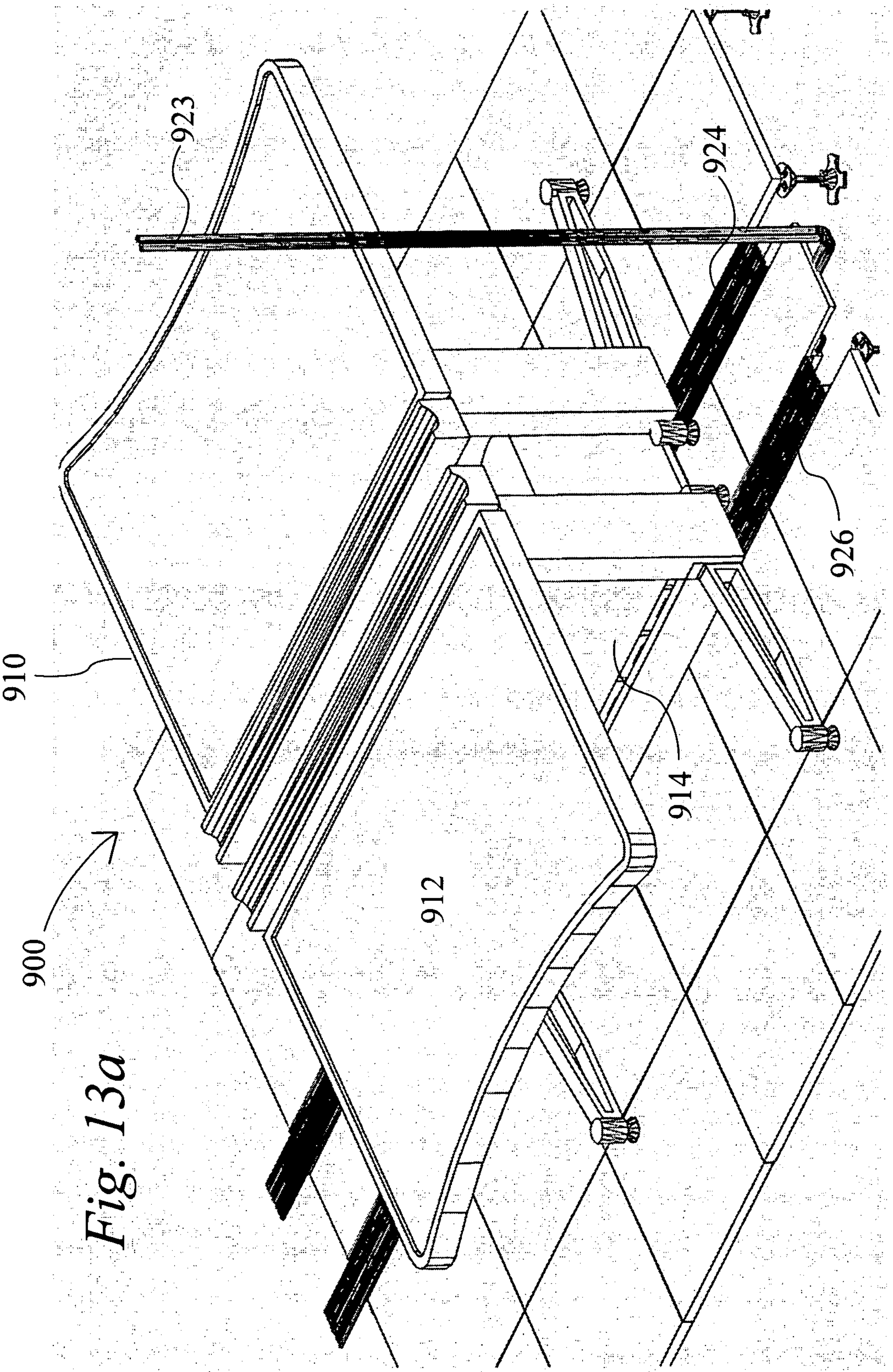


Fig. 13a

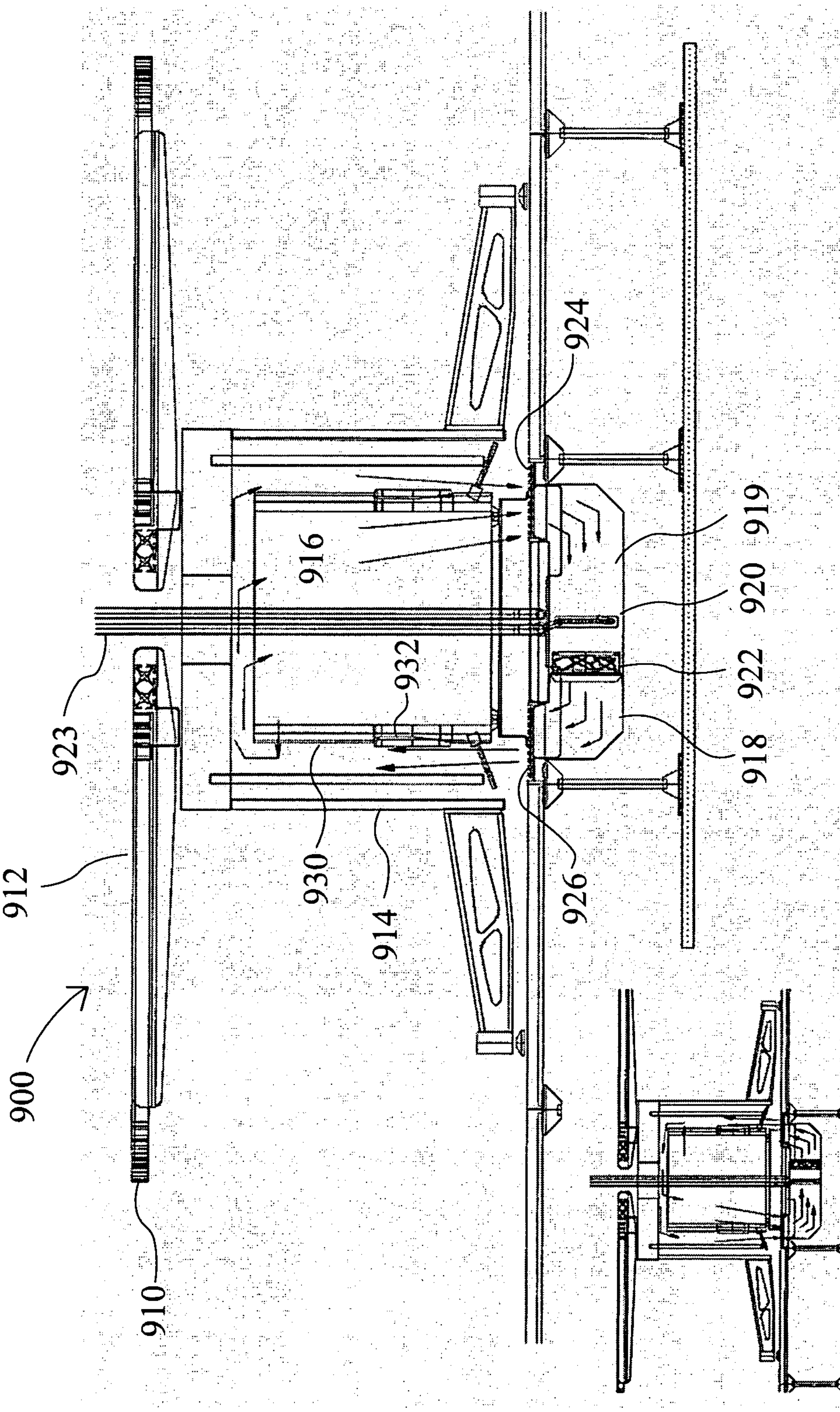
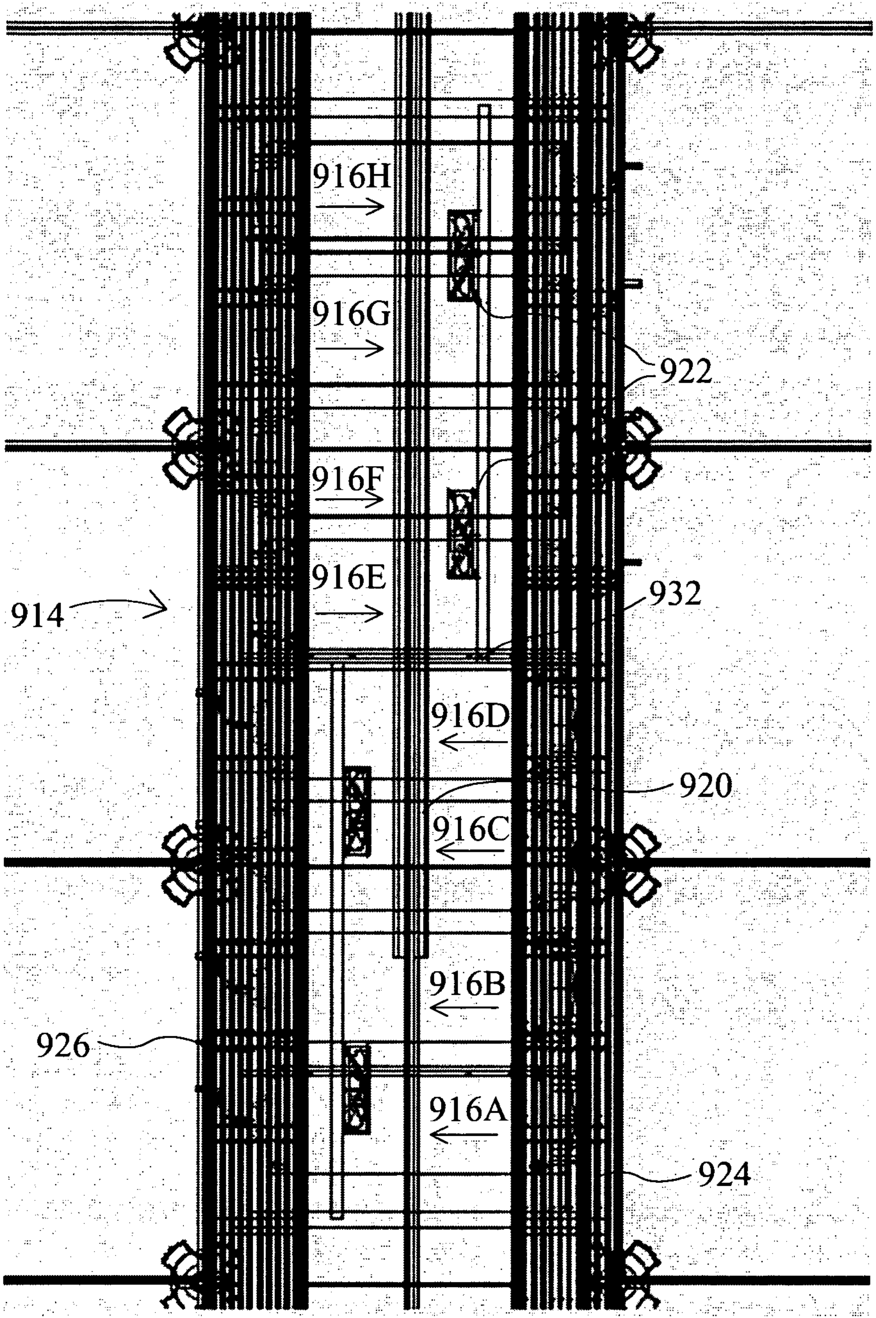


Fig. 13b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916D
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916C
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Fig. 13c

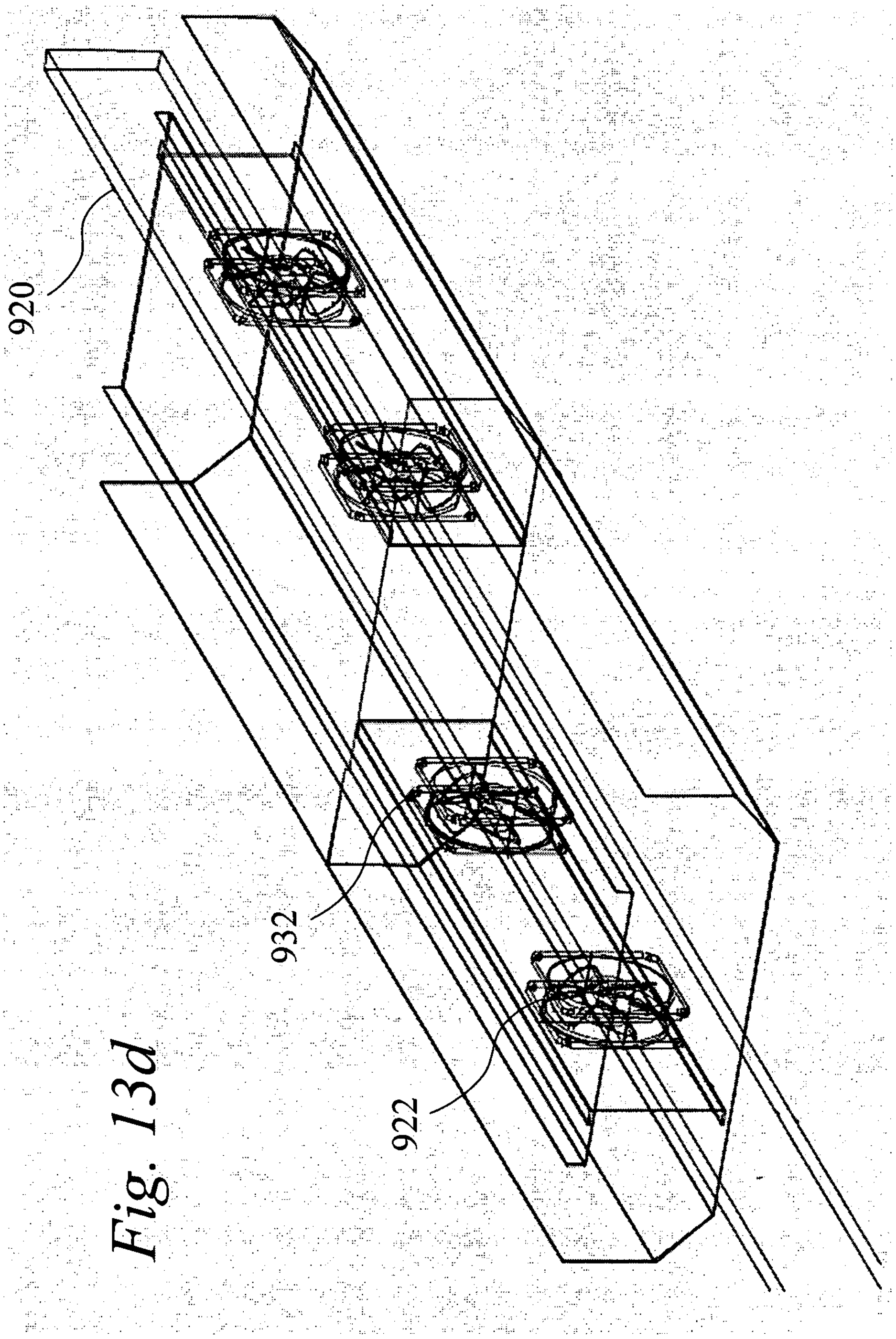

Fig. 13d

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/002534

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F1/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 940 270 A (PUCKETT JOHN CHRISTOPHER [US]) 17 August 1999 (1999-08-17) column 5, line 16 - column 6, line 42 figures 1-4 -----	1-19, 23-38, 40-49
X	US 2006/118279 A1 (STAFFORD ERIC [US]) 8 June 2006 (2006-06-08) paragraphs [0023] - [0033] figures 1-9 -----	1-8, 20-29, 34-49
X	US 5 706 668 A (HILPERT BERNHARD [DE]) 13 January 1998 (1998-01-13) column 2, line 40 - column 4, line 19 figures 1-3 ----- -/--	1-13, 23-38, 40-49

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 October 2007	05/11/2007

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Authorized officer
Baldan, Marco

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/002534

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2007/002534

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			CA 2581710	A1	30-03-2006
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