A building (40) comprises insulated walls (12), an insulated floor (14) and an insulated roof (16) and contains electrical equipment (20) which generates heat. An air conditioning unit (22) normally cools the enclosure (18) within which the equipment (20) is housed but should the air conditioning fail, increases in temperature in the enclosure (18) are initially absorbed by phase change material supported in tubes (28) on racks (30) adjacent the ceiling (32) of the enclosure (18). Fans (36) may be used to blow enclosure air over the tubes (28). The phase change material should have a transition temperature slightly above the normal operating temperature of the enclosure (18). Optionally, the building (40) includes a separate insulated room (42) which houses racks (46) of additional tubes (48) of phase change material. Communication between the enclosure (18) and room (42) is by way of fans (56) and (58) in the insulated wall (44) and said fans may be actuated when the temperature in the room (42) increases so that cooled air from the conditioner (22) chills the phase change material in the tubes (48). Should the air conditioner (22) fail, and the temperature increase to the extent that it cannot be controlled by the tubes (28), the fans (56 and 58) may be automatically actuated by a sensor (64) to circulate the enclosure air through the room (42).
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IMPROVEMENTS IN OR RELATING TO BUILDINGS

The present invention relates to buildings and is particularly concerned with buildings intended, even primarily intended, to house equipment which in use generates heat and which advantageously is maintained at as steady a temperature as reasonably possible.

Some equipment, for example electronic telephone equipment, which generates heat in its operation is adversely affected if its temperature rises above or falls below specific limits. Heat exchange with the ambient temperature in the building is in many cases the only practical, or economically acceptable, method of controlling the temperature of the equipment.

Accordingly, if the equipment is housed in a building which absorbs radiant heat from the sun during the day and radiates heat to the sky during
the night, the temperature of the air within the building must be controlled by artificial means, for example air conditioning. As such means requires energy for its operation, its use in remote, sparsely populated areas of the world is often impractical, or, if used, fraught with difficulties. Thus, it has been proposed to house telephone equipment in remote areas in dedicated buildings which may only be occasionally visited by service personnel and if the air conditioning breaks down or there is a power loss between visits the telephone equipment may be irreparably damaged by the ensuing temperature variations.

One solution to this difficulty is proposed in my Australian patent application no. 47850/85 in which the rate of change of temperature in the building is slowed by constructing the walls, floors and/or roof of the building of a material comprising a phase change material. Phase change materials are presently available commercially which have a large latent heat of fusion, so that a solid mass of the material at the fusion temperature absorbs a large amount of heat before changing to liquid at the same temperature. Examples of such materials are calcium chloride hexahydrate, lithium nitrate trihydrate and sodium sulphate decahydrate.

Various embodiments are proposed in my earlier patent application, some of which do away entirely with the use of a refrigeration unit. While these latter embodiments may be satisfactory in areas without a substantial range of temperature variation, there are also proposals incorporating a refrigeration unit so that if refrigeration is lost for some reason, the phase change material in the
structure of the building absorbs the initial heat gain within the building.

While these proposals have been found entirely satisfactory in experimental conditions, the need to change technologies in forming the structure of the building and the cost of incorporating the phase change material in the structure are disadvantageous to the proposals.

It is an object of the present invention to alleviate these disadvantages.

According to the present invention there is provided a building having insulated external walls and an insulated roof supported by the walls and comprising an enclosure adapted to contain electrical equipment which in use generates heat in the enclosure, means to circulate relatively cool air through the enclosure, the enclosure having a ceiling, and a multiplicity of envelopes of phase change material supported in the enclosure adjacent the ceiling in airflow communication with the circulating relatively cool air, the phase change material being solid at the normal operating temperature of the circulating cool air and at its fusion temperature being capable of absorbing heat before changing to a liquid phase at the same temperature.

By the present invention the phase change material is not incorporated in the structure of the building but instead is supported adjacent the ceiling of the enclosure for the electrical equipment, the area of potential maximum heat gain in the event of a temporarily insufficient or non-existent circulation of relatively cool air through the enclosure. The phase change material may
be contained in a relatively cheap and simple envelope and the walls and roof of the building are insulated to minimise heat gain within the enclosure during the day from incident solar radiation and heat loss from the building to atmosphere at night.

Conveniently, the phase change material (PCM) is enveloped in closed tubes of plastics materials but other envelopes, preferably having shapes providing volumes of phase change material contained with a large surface area to weight ratio, will be satisfactory. Polyvinylchloride tubes about one metre long and 38 - 40 mm in diameter are preferred, but alternatives are balls, ovals and small panels.

Since in normal use in accordance with the present invention the relatively cool air circulating through the enclosure maintains the equipment within a desired temperature range, the phase change material is used in a defensive manner, that is in the event of a loss of circulating cooling air.

Ideally, the building according to the present invention should contain an adequate amount of PCM such that there is sufficient heat transfer surface area to limit the temperature rise following a loss of cooling to the safe upper limit temperature of the electronic equipment for a sufficient period of time to enable a maintenance person to arrive on site and take corrective action to restore the normal cooling effect.

It will be appreciated that the normal cooling will be controlled so that the environment which houses the PCM is maintained at a temperature which is below the phase change temperature of the associated PCM. This will ensure that cooling is
stored both within the sensible heat and the latent heat of fusion of the PCM.

If excessive amounts of the phase change material are used, the temperature within the enclosure will effectively be maintained constant, but unnecessary expense will have been incurred. If less than the ideal amount of phase change material is employed, the rate of temperature rise within the building will be excessive, and the available safe time for a recall mechanic to arrive at the site to correct the faulty cooling plant will be inadequate. It will also be appreciated that a greater quantity of PCM will further delay the rate of temperature rise and the available safe recall time to allow a maintenance person to arrive on site will be greater.

In addition to suspending phase change material adjacent the ceiling, additional envelopes of PCM could be supported within the enclosure around the walls thereof. The preferred operating temperature of the electrical equipment is about 28°C and advantageously a PCM having a phase transition temperature slightly above this, or a series of phase change materials having a range of transition temperatures slightly above this, is used in the envelopes adjacent the enclosure ceiling. A preferred material is sodium sulphate decahydrate which has a phase transition temperature of about 31°C and a latent heat of 40.33 cal/gm, for example a product marketed under the trade name CALORTHERM PCM31.

Conveniently, the envelopes of phase change material are supported on open racks immediately beneath the enclosure ceiling. The racks may be inclined to the horizontal. With a basic PCM
temperature limiting system where the PCM has been installed in the form of tubes about 1 metre long by 38 - 40 mm diameter, mounted on perforated inclined racks just below the ceiling in electronic equipment rooms the system is extremely simple because there are no moving components, no control system to operate the PCM, and there is minimal need for maintenance because of the extreme simplicity. It will also be appreciated that heat transfer from the heated air into the PCM will be enhanced by use of one or more fans to create a better air movement to improve the heat transfer coefficient of the air/PCM envelopes. Advantageously the fan or fans have a dedicated power supply so they are not affected if the reason for the temperature increase in the enclosure is a loss of supply to the cooling system. The fan or fans may be controlled to come on automatically when the enclosure temperature increases above a desirable degree.

The enclosure may be defined by the insulated external walls and the insulated roof of the building, and the building preferably has an insulated floor. Alternatively the enclosure may comprise only part of the building. Thus in one embodiment the building includes a space separate from the enclosure, an air flow input to the space, an air flow output from the space to the enclosure, means to direct air from the input through the space to the enclosure by way of the output, and the space containing a multiplicity of envelopes of phase change material. The envelopes of PCM in the space may be supported on arrays of racks and advantageously the space is insulated so that ambient external temperature has negligible effect on the PCM.
The aforementioned space may comprise an area of the building separated from the enclosure by a common insulated wall or the space may be defined between a raised floor of the enclosure and the floor of the building. The air flow input may communicate between the enclosure and the space, in which case, advantageously the enclosure and space are closed to exterior air and a refrigeration unit is provided in the air flow input or the enclosure is open to cool air. Alternatively, the space is capable of communicating directly with the exterior air so that at least part of the circulating air in the enclosure is ambient exterior air and an exhaust may be provided in the space. A refrigerator unit may be provided to introduce cooled air directly into the space from exteriorly of the building and the refrigerator unit may be automatically controlled according to the temperature in the space or in the enclosure. The means to direct air from the output through the space to the enclosure by way of the output may comprise a fan in an air flow passage communicating with the enclosure and the space; and such fan may be automatically actuable when the temperature in the enclosure increases to a predetermined level. Two fans may be provided respectively in the air flow input and the air flow output. Alternatively, or in addition, the aforementioned refrigeration unit may comprise the air directing means. Preferably the fan or fans of the air directing means have a dedicated power supply, which may be the same dedicated power supply as powers the optional fan or fans directing air flow over the envelopes of phase change material adjacent the enclosure ceiling. Flow communication between the space and the enclosure may be able to be shut
off.

In an alternative embodiment, the enclosure has at least one wall and/or the ceiling remote from the walls and/or roof of the building and external air is permitted to circulate over the exterior of said enclosure wall or walls and/or ceiling and said enclosure wall or walls and/or ceiling are capable of conducting heat therethrough.

Advantageously, a refrigeration unit is provided to introduce cooled external air directly into the enclosure. The refrigeration unit, such as a room air conditioner, may be automatically controlled according to the temperature in the enclosure, and the enclosure may be closed to air other than through the refrigeration unit. In cooler climates the principal cooling of the enclosure may be uncooled external air and the refrigeration unit may be only necessary under hot atmospheric conditions. This is particularly advantageous to reduce service requirements of the refrigeration unit and to reduce running costs. Thus the enclosure may include an air flow inlet and air flow outlet respectively directly from and to atmosphere and fan means to pass external air from said air flow inlet to said air flow outlet. Advantageously the air flow outlet is disposed in the enclosure ceiling and the fan means is controlled by a variable volume fan speed control unit having a sensor measuring the enclosure air temperature.

Any of the aforementioned optional features may be used in suitable combination with any other such features.

Various embodiments of a building in accordance with the present invention will now be
described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a front sectional view of a basic first embodiment of the building;

Figure 2 is a view similar to Figure 1 of a second embodiment which includes a separate space for additional PCM;

Figure 3 is a view similar to Figure 1 but showing the second embodiment modified to include a refrigeration unit introducing cooled air directly into the separate space;

Figure 4 is a view similar to Figure 1 but showing a third embodiment of the building;

Figure 5 is a view similar to Figure 1 but showing a fourth embodiment of the building;

Figure 6 is a view similar to Figure 1 but showing a fifth embodiment of the building; and

Figure 7 is a view similar to Figure 1 but showing a sixth embodiment of the building.

Referring firstly to Figure 1, a building 10 comprises insulated walls 12, floor 14 and roof 16. The walls, floor and roof of the building 10 define an enclosure 18 which houses telephone electronic equipment 20 supported on the floor 14. The insulated building 10 minimises heat gain and loss from the enclosure 18 so as to reduce the range of temperature variation within the enclosure over a 24-hour period. The insulation may be equivalent to 100 mm thickness of rockwool. The equipment 20 generates heat during use within the enclosure and in order to maintain the temperature at about the desired level of 28°, an air conditioner 22 having an inlet 24 and an outlet 26 is mounted in one of the insulated
walls 12.

Should the air conditioner 22 fail through loss of mains power or through failure of the cooling plant itself, heat from the equipment 20 will cause the temperature in the enclosure 18 to increase, and without some means to delay the increase in temperature until the normal cooling can be restored, the equipment 20 may be damaged.

Tubes 28 of phase change material are supported by expanded mesh perforated racks or trays 30 adjacent the ceiling 32 of the enclosure 18 defined by the roof 16 of the building. The racks 30 may be supported by any appropriate means (not shown) such as straps extending from the ceiling and are inclined to the horizontal as shown by the two right hand most racks in Figure 1. The other two racks 30 are shown rotated through 90° for purposes of description only and in use will extend in parallel array with the right hand two racks. The second rack from the left hand end in Figure 1 is shown without any tubes 28 thereon also for illustrative purposes. The tubes 28 may merely rest on the racks and to prevent them rolling off, the racks have an end wall 34. The phase change material is preferably sodium sulphate decahydrate sold under the trademark CALORTHERM PCM31 which has a phase change temperature of 31°C, slightly above the normal operating temperature of 28°C of the enclosure 18. Thus, during normal air conditioning of the enclosure 18 the phase change material in the tubes 28 is solid. As the heat generated by the equipment 20 rises under normal convection circumstances towards the ceiling 32 when the air conditioner 22 is not functioning, the heat is absorbed by the phase change material
until it is transformed into a liquid phase at its latent heat of fusion. This is done without a change in temperature of the phase change material so that the increase in temperature in the enclosure 18 is delayed. The volume of phase change material in the tubes is advantageously provisioned to match the recall time for a service mechanic to reinstate the normal cooling and to match a rate of acceptable temperature rise over that period. The volume required in any particular circumstance may be readily ascertained by those skilled in the art.

The tubes 28 are preferably of black polyvinylchloride, each about one metre in length and having an internal diameter of about 38 mm. One or more fans 36 (only one shown) may be supported within the enclosure 18 by suitable means to blow air within the enclosure over the tubes 28 so as to increase the rate of heat transfer from the air into the phase change material. The fan 36 preferably has a dedicated power source and is automatically actuated when the air conditioner 22 stops functioning or when a temperature sensor 38 in the enclosure measures a non-acceptable increase in temperature. The electrical power system to operate the fan 36 can either be DC batteries wired direct to a DC operated fan or DC batteries wired through an inverter of suitable capacity to operate an alternating current fan. The batteries may be recharged from a solar collector (not shown).

In the remaining figures, the above described basic principals of the building in accordance with the present invention are essentially present and where the details are repeated in the embodiments, they will not be described further.
Likewise, the same reference numerals will be used for the same or similar parts.

Referring now to Figure 2, in the building 40 shown therein, the enclosure 18 does not occupy the whole of the building but instead is separated from a room 42 by a well insulated transverse wall 44. The room 42 is substantially filled with a vertical array of racks 46 supporting tubes 48 of phase change material which are identical to the tubes 28 and contain the same phase change material. The racks 46 have an open arrangement and are also conveniently formed of expanded mesh. The racks 46 may be supported in spaced apart manner by any suitable means. The room 42 has a small opening 50 to exterior air through the roof 16 of the building 40, by way of a passage 52 which opens into the room by way of louvres 54 which may be closed. The opening 50 and passages 52 may be removed.

The insulated wall 44 has upper and lower fans 56 and 58 mounted for rotation therein, the upper fan 56 being actuable to direct air from the enclosure 18 into the room 42 while the lower fan 58 is actuable to direct air from the room into the enclosure 18. Each of the fans 56 and 58 has a set of louvres 60 on the downstream side thereof which are spring loaded into the closed condition and which are opened as shown automatically by the blast of air from the respective fan. The fans 56 and 58 preferably have a dedicated power supply which may be the same power supply as for the fans 36, and therefore may be as described with reference to the fans 36.

The normal air conditioned operation of the enclosure 18 in the building 40 is identical to that described with reference to the building 10 but it
will be appreciated that the cool storage capacity has been extended from the enclosure 18 to the room 42. Thus, in normal operation, the air conditioner 22 operates to remove the heat generated by the electrical equipment 20 and to maintain the air temperature in the enclosure 18 below the phase change temperature of the phase change material. Also under normal operating conditions, the fans 56 and 58 are not operating and the louvers 60 are closed.

A temperature sensor 62 is provided in the room 42 and when the temperature sensor determines that the temperature in the room 42 is at or above the phase change temperature of the phase change material in the tubes 48 the fans 56 and 58 will be automatically actuated to circulate cooling air between the enclosure 18 and the room 42. This action permits the cool air from the air conditioner 22 to circulate into the room 42 to cool down the phase change material in the tubes 48 and to thereby retain it in a solid phase. At the desired lower temperature in the room 42 the temperature sensor 62 deactuates the fans 56 and 58 and the air conditioner 22 will then continue to cool just the enclosure 18.

When the air conditioner 22 ceases to provide a cooling effect and temperature sensor 38 determines an increase in temperature in enclosure 18, it will automatically actuate the fans 36 in the manner described with reference to Figure 1. If enclosure 18 continues to get too hot, or additional time is needed to reactivate the air conditioner 22, a temperature sensor 64 in the enclosure 18, which may in practice be the same temperature sensor 38 set to measure a second higher temperature, actuates the
fans 56 and 58 in the insulated wall 44 so as to transfer the stored cool air in the room 42 into the enclosure 18.

Referring now to Figure 3, the building 40 is modified compared to that shown in Figure 2 in that the room 42 has its own dedicated air conditioner 66 which is controlled by temperature sensor 62 to keep the temperature in the room below the phase change temperature of the material in tubes 48. Thus, instead of actuating the fans 56 and 58 so that the air conditioner 22 is used to cool the tubes 48, the temperature sensor 62 actuates the dedicated air conditioner 66. The conditioner 66 may be similar to those cooling units which are used for transportable refrigerated type cool room trucks which are normally used for the cool storage and transport of food products.

Above the conditioner 66 is a sun shield 68 which shades the condensing unit of the conditioner to alleviate adverse effects of the condensing unit being exposed to direct sunlight. The conditioner 66 in use directs cooled air through the inlet 50 in the roof 16 of the building into the passage 52 and into the room 42 by way of the louvres 54 which are spring loaded into the closed condition but opened under the influence of the forced air from the conditioner 66. The cooled air then passes over the tubes 48 through the racks 46 and is returned to the conditioner 66 by way of a louvred second opening 70 in the roof 16.

In all other respects, the operation of the building 40 in Figure 3 is identical to that in Figure 2.

In Figure 4, the building 80 may be similar to the modified building 40 of Figure 3 and operate
the same way. As illustrated, the enclosure 18 has, apart from the common insulated wall 44 with the room 42, thermally transparent walls 82 within the insulated building defined by the roof 16 and walls 12. Additionally, the ceiling 32 of the enclosure 18 and the floor 84 are thermally transparent and like the walls 82 may be formed of thin metal sheeting. The walls 82 and ceiling 32 are spaced respectively from the walls 12 and roof 16 to define an air passage 86 therebetween which is open to external air at 88. Since the floor 84 of the enclosure 18 is thermally transparent, the building 80 is supported off ground level 90 by legs 92. Also the roof 94 of the enclosure 42 is separate from the roof 16 of the building but is otherwise similar to the identical portion of the roof 16 in the modified building 40 of Figure 3. In Figure 4, the air conditioner 66 is protected from direct sun by the roof 16. Finally, the equipment 20 is supported off the floor 84 of the enclosure 18 by a suitable deck 96.

In the arrangement described with reference to Figure 4, under normal operating conditions heat loss from the equipment 20 may be through the thermally transparent walls 82 and ceiling 32 of the enclosure to atmosphere so that the air conditioner 22 need not be used full time. Other than this the operation may be as described with reference to Figure 3.

In an alternative version of Figure 4, the front and rear thermally transparent walls 82 (the front wall not being shown in the illustrated section) are open to atmosphere and are not protected by any thermal insulation, and the roof 16 of the building merely acts as a sun shade. The room 42
remains fully insulated. This type of building has the advantage that it is possible to design the thermally transparent inner enclosure to naturally dissipate the heat generated from the equipment 20 through the thin metal walls directly to the external cooling air, which will provide a useful measure of energy conservation. It will be appreciated that such a thermally transparent equipment enclosure 18 will only be able to dissipate heat dependent on the outside air temperature and the thermal gradient between the outside air temperature and the temperature inside the enclosure. When the outside air temperature becomes too hot for the thermally transparent enclosure to dissipate sufficient heat to maintain the enclosure within specified limits the thermostat 64 may automatically turn on the fans 56 and 58 to circulate the warmer air between the enclosure 18 and the room 42 which has been cooled in the manner described with reference to Figure 3.

Prior to this, the temperature sensor 38 may have actuated the fans 36 to blow air over the phase change material in tubes 28 and this must clearly be done prior to the phase change material turning to a liquid phase. Conveniently, the conditioner 66 is actuated to cool the PCM tubes 48 in the room 42 at night to make use of the lower cost of electricity which is available under many circumstances during that period. The conditioner 22 in the enclosure 18 may be available as standby cooling only to operate in times when either the conditioner 66 or the fans 36 and/or 56 and 58 fail. Alternatively, as before with reference to Figure 3, the conditioner 22 may be used as the third line of defence after the thermal transparency of the walls 82 and ceiling 32 and the
heat absorption of the PCM tubes 28 to cool the enclosure 18, with the fans 56 and 58 only being actuated after the conditioner 22 has proved insufficient or if it should fail.

The building 100 proposed in Figure 5 is essentially the same as the building 10 of Figure 1 except that it is proposed for use in lower temperature environments, particularly where the average temperature is below the preferred 28°C operating temperature of the equipment 20, so that external air is well able to cool the enclosure 18 under most operating conditions. Thus, the air conditioner 22 is used for extreme heat conditions only and the enclosure 18 has an external air inlet 102 in an end wall 12 of the building adjacent the floor 14. An air outlet 104 is mounted in the roof 16, to take out the hottest air in the enclosure 18, to the side of the equipment 20 opposite to the air inlet 102 so that there is a fresh air flow over the equipment 20.

The air intake 102 should incorporate an appropriate filter to alleviate dust entry into the enclosure 18. The Email deep-bed pyrocube or multi-vee filter may be appropriate and the pyrocube filter is particularly suitable because of a high dust holding capacity (10 kg) with associated long life, low resistance and low maintenance requirements.

The air outlet 104 incorporates a centrifugal roof ventilator fan 106 of sufficient capacity to extract the normal heating load and is conveniently fitted with a variable volume automatic controller (not shown) which is capable of maintaining a relatively constant temperature within the enclosure 18 under normal operating conditions,
whilst also maintaining a reduction in energy input to satisfy the cooling load. The variable volume flow rate controller of the fan 106 may be actuated by a temperature sensor 108 in the enclosure. The controller may be incorporated in the sensor 108. A low resistance air filter 110 is provided within the enclosure 18 at the outlet 104 to alleviate blow back dust passing through the exhaust fan into the enclosure.

The volume air flow through the fan 106 should be sufficient under normal operating conditions to maintain the phase change material in the tubes 28 solid and when the fan 106 is incapable of coping with a heat rise in the enclosure 18 due to excessive conditions externally of the building 100, the temperature increase registered by the sensor 108 may actuate the air conditioner 22 while at the same time deactuating the fan 106. Automatic louvres (not shown) may be provided in the outlet 104 to close when the fan 106 is not in use.

In the event of total failure of the mains power so that neither the fan 106 nor the air conditioner 22 operates, a temperature increase in the enclosure 18 may be sensed by the temperature sensor 38 to actuate the fans 36 to blow air over the tubes 28 as previously described.

In Figure 6, the building 120 comprises the enclosure 18 and a PCM storage room 42. The building 120 is distinguished from, for example, the building 40 in Figure 2 in that provision is made for 100 percent air cooling using fans for both the enclosure 18 and for the room 42 so that principally all of the cooling of the PCM material in the room 42 and on the racks 30 is by low ambient temperature external air.
This is possible in those hot countries with very cold nights such as in the Middle East where the cooling captured in the PCM material may be all that is needed for most of the year.

The building 120 is similar to the building 100 in Figure 5 except that the air intake 102 and the outlet 104 are disposed in the room 42 to blow cool external air directly through the room. As in other embodiments utilising the separate insulated room 42, the phase change temperature of the phase change material in the tubes 48 may be lower than that in the tubes 28 in the enclosure 18. Thus the room 42 may maintain a cooler temperature than the phase change material in the tubes 28 is capable of.

The intake 102 and outlet 104 incorporate automatic louvred dampers 122 which are suitably well insulated. Additionally, a sun screen 124 is provided over the outlet 104.

In use of the building 120, when the outside air temperature is cold and less than the temperature of the room 42, the fan 106 is actuated and dampers 122 automatically open so that the outside air flows through the air filter in intake 102, over the PCM tubes 48 on the racks 46 in room 42 and exhaust to atmosphere through the outlet 104. When the PCM in tubes 48 is fully cooled or regenerated, the fan 106 stops and dampers 122 close to maintain the cool store. The actuation of the fan 106 may be by a temperature sensor 62. When cooling is needed in the enclosure 18, the fans 56 and 58 are actuated by the sensor 64 so that cool air from the room 42 is circulated through the enclosure 18. Prior to this, as before, the fan or fans 36 may be actuated by the sensor 38 to blow air in the enclosure 18 over the
tubes 28 adjacent the ceiling 32.

The air conditioner 22 may be reserved for very hot days when the cool storage in the PCM tubes 28 and 48 is insufficient or when the cool storage system of room 42 fails.

Referring now to Figure 7, the building 130 is similar to the building 10 except that the electrical equipment 20 is supported on a raised modular floor 132 of the enclosure 18. A passage 134 is defined between the raised floor 132 and the floor 14 of the building. Racks 136 carrying tubes 138 of phase change material are supported in inclined manner in a horizontal array in the passage 134 and air cooled in the passage 134 by the tubes 138 escapes into the enclosure 18 by way of modular vents 140 in the floor 132. The racks 136 are of similar construction to the racks 30 and may be supported by any appropriate means. The tubes 138 are identical to the tubes 28 but the phase change material is preferably such that its phase change temperature is rather below the normal operating temperature in the enclosure 18 of 28°C. Advantageously the phase change material in the tubes 138 has a transition temperature of about 18°C. The advantage of the modular floor 132 is that electrical cabling and other provisions for the enclosure 18 may pass along the passage 134. The passage 134 is extended at each end 142 and at least one air conditioner may be provided to blow cooled air through the passage. Such air conditioner may be similar to the air conditioner 22 and thereby blow cooled external air into the passage 134, but advantageously and as shown the building 130 is substantially closed and external air conditioning units 144 have respective cooling coils 146 disposed
in each end portion 142 of the passage 134. Advantageously the air conditioners 144 are of modular form and incorporate respective modular fan units 148 which draw air from the enclosure 18 through louvres 150 which may be spring loaded and closed when the fans 148 are not operational. In addition, or alternatively, to the passage 134 under the modular floor 132, racks of phase change material may be supported above a false ceiling of the enclosure 18 having similar vents for access of hot air.

In normal use, cooling of the enclosure 18 is by way of the cooling coils 146 and fans 148 drawing air from the enclosure through the vents 150 and up through the vents 140 back into the enclosure. If the air conditioners 144 fail, heat generated by the equipment 20 is initially absorbed by the phase change material in tubes 28 and fan 36 may be actuated by temperature sensor 38 to blow air over the tubes. At the same time, if the fans 148 continue to operate air drawn through the vents 150 will pass over the tubes 138 of phase change material in the passage 134 and will thereby continue to blow cool air through the vents 140. The phase change material in the passage 136 will be chilled to the normal operating air temperature generated by the air conditioner 144 and this may be as low as 15°C so that a considerable reserve of cool air is available.

As an optional modification of the building 130, a fan 152 may be disposed in the passage 134 to draw air from the enclosure 18 through a grid 154 over the phase change tubes 138 and out of the vents 140. The fan 152 should have a dedicated power supply which may be the same power supply as the fan 36 and be automatically actuated by a temperature
sensor 156 when the temperature in the enclosure 18 increases due to failure both of the air conditioning units 146 and the fans 148. A louvre 158 is provided between the grid 154 and the inlet to fan 152 and is normally biased to a closed position so that chilled air blown by the fans 148 does not escape through the grid 154. The louvre 158 is opened by the force of air drawn into the fan 152 when it is actuated.

While several embodiments of the present invention have been described, it will be appreciated by those skilled in the art that many modifications and variations may be made and all such modifications and variations should be considered as within the scope of the present invention. In particular, it will be understood that one feature of any one of the described embodiments may be selectively incorporated in any other of the described embodiments. Additionally, it will be understood that the described modification of Figure 4 is within the scope of the present invention. It is to be also understood that the embodiment of Figure 7 may be used without the PCM tubes adjacent the ceiling.
CLAIMS:

1. A building having insulated external walls and an insulated roof supported by the walls and comprising an enclosure adapted to contain electrical equipment which in use generates heat in the enclosure, means to circulate relatively cool air through the enclosure, the enclosure having a ceiling, and a multiplicity of envelopes of phase change material supported in the enclosure adjacent the ceiling in airflow communication with the circulating relatively cool air, the phase change material being solid at the normal operating temperature of the circulating cool air and at its fusion temperature being capable of absorbing heat before changing to a liquid phase at the same temperature.

2. A building according to claim 1 wherein the enclosure is defined by the insulated external walls and the insulated roof.

3. A building according to claim 1 wherein the building has an insulated floor.

4. A building according to claim 1 which includes a space separate from the enclosure, an air flow input to the space, an air flow output from the space to the enclosure, means to direct air from the input through the space to the enclosure by way of the output, and the space containing a multiplicity of envelopes of phase change material.

5. A building according to claim 4 wherein the space is insulated.
6. A building according to claim 4 wherein the space and enclosure are separated by a common insulated wall.

7. A building according to claim 4 wherein a floor of the enclosure is raised above a floor of the building and said space is defined therebetween.

8. A building according to claim 4 wherein the air flow input communicates between the enclosure and the space.

9. A building according to claim 8 wherein the space is closed to exterior air and a refrigeration unit is provided in the air flow input.

10. A building according to claim 4 wherein the space is capable of communicating directly with the exterior air.

11. A building according to claim 10 wherein the air flow input comprises a refrigerator unit to introduce cool air directly into the space from exteriorly of the building, said refrigeration unit being automatically controlled according to the temperature in the space or in the enclosure.

12. A building according to claim 4 wherein the air directing means comprises a fan in an air flow passage communicating with the enclosure and the space, and the fan is automatically actuable when the temperature in the enclosure increases to a predetermined level.
13. A building according to claim 12 wherein two fans are provided respectively in the air flow input and the air flow output.

14. A building according to claim 4 wherein the air directing means has a dedicated power supply.

15. A building according to claim 4 wherein air flow communication between the space and the enclosure is capable of being shut off.

16. A building according to claim 1 wherein the enclosure has at least one wall and/or the ceiling remote from the walls and/or roof of the building and external air is permitted to circulate over the exterior of said enclosure wall or walls and/or ceiling and wherein said enclosure wall or walls and/or ceiling are capable of conducting heat therethrough.

17. A building according to claim 1 wherein a refrigeration unit is provided to introduce cooled external air directly into the enclosure.

18. A building according to claim 17 wherein the refrigeration unit is automatically controlled according to the temperature in the enclosure.

19. A building according to claim 17 wherein the enclosure is closed to external air other than through the refrigeration unit.
20. A building according to claim 1 wherein the enclosure includes an air flow inlet and an air flow outlet respectively directly from and to atmosphere and fan means to pass external air from said air flow inlet to said air flow outlet.

21. A building according to claim 20 wherein the air flow outlet is disposed in the enclosure ceiling.

22. A building according to claim 20 wherein the fan means is controlled by a variable volume fan speed control unit having a sensor measuring the enclosure air temperature.

23. A building according to claim 1 wherein at least one circulating fan is provided in the enclosure to circulate air in the enclosure over the envelopes of phase change material.

24. A building according to claim 23 wherein the at least one circulating fan has a dedicated power supply.

25. A building according to claim 1 wherein each envelope of phase change material comprises a closed tube.

26. A building according to claim 1 wherein the envelopes of phase change material are supported on open racks immediately beneath the enclosure ceiling.

27. A building according to claim 26 wherein the racks are inclined to the horizontal.
28. A building according to claim 1 wherein the envelopes contain phase change materials having a variety of fusion temperatures so as to absorb heat in the enclosure over a wide band of temperature range.

29. A building according to claim 1 wherein additional envelopes of phase change material are supported within the enclosure around the walls thereof.
**INTERNATIONAL SEARCH REPORT**

**International Application No:** PCT/AU 88/00038

### I. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both National Classification and IPC.

- Int. Cl. 4
  - E04B 1/76, E04H 9/16

### II. FIELDS SEARCHED

**Classification System**

- IPC: E04B 1/76, E04H 9/16

**Minimum Documentation Searched**

**Classification Symbols**

### III. DOCUMENTS CONSIDERED TO BE RELEVANT

#### Category **Y**

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<th>Citation of Document</th>
<th>with indication, where appropriate, of the relevant passages</th>
<th>Relevant to Claim No. <strong>9</strong></th>
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<tr>
<td>Y US, A, 4178727 (PRUSINSKI et al) 18 December 1979 (18.12.79) See column 1 line 51 and column 3 lines 49-54.</td>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>Y US, A, 4003426 (BEST et al) 18 January 1977 (18.01.77) See column 1 lines 1-20 and column 4 lines 55-60.</td>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>Y AU, A, 47850/85 (PRUDHOE) 10 April 1986 (10.04.86) See page 3 lines 32-38 and page 4 lines 13-33.</td>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>Y FR, A, 2540235 (SOCIETE NATIONALE ELF AQUITAINE) 3 August 1984 (03.08.84) See page 7 lines 31-33.</td>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>Y FR, A, 2400088 (CENTRE SCIENTIFIQUE ET TECHNIQUE DU BATIMENT) 9 March 1979 (09.03.79) See page 3 lines 7-11 and 17-19.</td>
<td>(1)</td>
<td></td>
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**IV. CERTIFICATION**

**Date of the Actual Completion of the International Search:**
5 May 1988 (05.05.88)

**Date of Mailing of the International Search Report:**
19 May 1988

**International Searching Authority:**
Australian Patent Office

**Signature of Authorized Officer:**
Hugh Ness

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 88/00038

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<tr>
<td>US 4178727</td>
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