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NOTICE OF ENTITLEMENT

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being the applicants in respect of Application No. state the following:-

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HYCO PTY LTD and POSEIDON SCIENTIFIC INSTRUMENTS PTY LTD, the persons nominated for the grant of the patent are the applicants of the application listed in the declaration under Article 8 of the PCT and derive rights in this invention from the inventors by virtue of an assignment.

The basic application listed on the request form is the first application made in a convention country in respect of the invention.

DATED THIS 12TH DAY OF AUGUST 1993

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Abstract

(57) Claim

25. A system as set forth in claim 23, wherein said at least one manifold includes an elongated passageway extending between the fluid inlet and fluid outlet, the elongated passageway having a cross section of 5mm or less.

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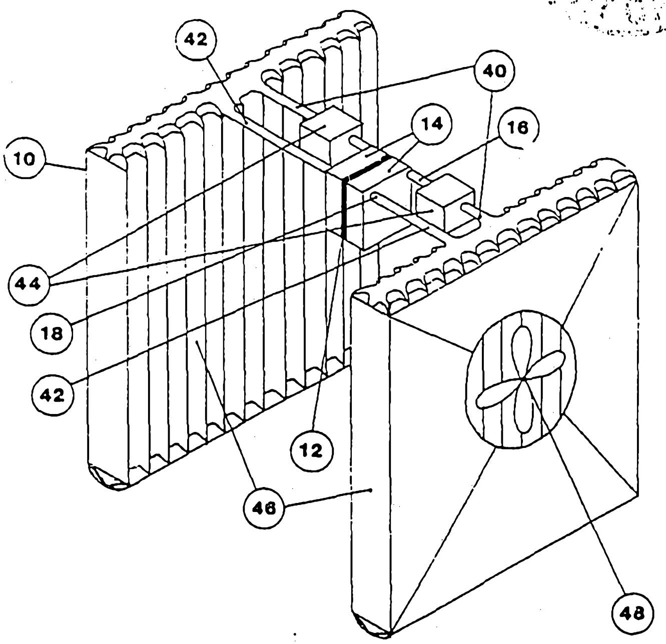


(57) Abstract

A thermoelectic system (10) comprises a thermoelectric module (12), volume defining manifolds (14) attached to opposed faces of the module (12) and pump means (44) for circulating fluid from remote heat exchangers (46) to the manifolds (14). There is also described a novel submersible pump (78) having stationary electric coil means (84) and rotatable magnet housing (86) and associated impeller (88). A magnet means (92) in the magnet housing (86) is disposed about the electric coil means (84). Still further, there is described a novel thermoelectric module containing a row of spaced thermocouples (130). Adjacent thermocouples (130) are connected together by blocks (144) of electrically conductive material said blocks being relatively large in size and immersed in a pumped, electrically non-conductive fluid.

TITLE

"IMPROVEMENTS IN THERMOELECTRIC REFRIGERATION"

DESCRIPTION

The present invention relates to thermoelectric refrigeration systems.

FIELD OF THE INVENTION

It is known to use thermoelectric modules in refrigeration systems. A thermoelectric module is a known type of heat pump in which the passage of an electric current through the module causes one side of the module to be cooled and the opposite side of the module to be heated. Thermoelectric modules are also known as Peltier modules or thermoelectric heat pumps.

Previously known refrigeration units containing thermoelectric modules have comprised aluminium heat sinks which are clamped tightly to each side of the thermoelectric module, creating a thermoelectric assembly. When an electric current is applied to the module, heat is pumped from one side to the other side. Initially, when a current is first applied to the thermoelectric module the temperature differential between the two sides is at a minimum. Under these conditions the thermoelectric assembly offers efficient performance. However, as the refrigerator approaches its desired internal temperature there is an increased temperature difference between the two sides. Under these conditions the thermoelectric assembly becomes less efficient as a heat pump.

When the thermoelectric module is configured as a heat pump a conventional thermoelectric assembly must always have an electric current applied to it in order to maintain a temperature differential across the device. If this current is removed then heat will flow through the assembly in such a manner as to re-establish thermal equilibrium. Therefore, in practice, conventional thermoelectric assemblies consume power simply to maintain a temperature difference across the assembly. This is very wasteful of energy.

In practice, conventional thermoelectric assemblies also suffer from the effects of thermal impedances which occur at the boundaries of the thermoelectric module and the heat sinks. This requires great care and expense in the manufacture of thermoelectric assemblies to ensure the minimisation of these boundary effects.

Some thermoelectric assemblies have two small thermoelectric modules sandwiched between heat sinks rather than a single thermoelectric module in an effort to try and increase the surface area contact with the heat sinks. However, the structural and design limitations of thermoelectric modules forced on them by the clamping forces of solid heat sinks and cost, restrict the modules themselves to being necessarily small, clearly preventing large area thermal contact.

Also, for the same reasons, electrical connectors between P & N thermocouples within thermoelectric modules are very small. This is restrictive as improved performance can be achieved by utilising greater thermal area contact via large thermal connections.

Another major limiting factor in conventional thermoelectric module design is the fact that the hot and cold faces of the modules are close together (usually within 5mm). There are very significant losses through convection, conduction and radiation from one face to another i.e. high heat transfer. This greatly limits the ultimate performance of the thermoelectric modules.

Exacerbating this problem even further in conventional thermoelectric assemblies is the fact that the solid heat sinks attached to the module faces are in close proximity to one another. The thermal mass and close proximity of the two heat sinks in a conventional thermoelectric assembly constantly work against one another.

The abovementioned problems have restricted the use of the thermoelectric assemblies to very small, portable coolers and refrigerators. Thermoelectric assemblies have not been practical for use in domestic refrigeration because of, for example, the high power consumption.

SUMMARY OF INVENTION

The present invention provides thermoelectric systems suitable for use in refrigeration in which at least some of the problems of the prior art are alleviated.

The present invention provides a very significant break through as it has been discovered that under certain conditions of geometry and extremely high fluid turbulence, unexpected improvements in efficiency can be obtained. Under these conditions the fluid in a heat exchange manifold significantly improves the transfer of heat while reducing the power needed to pump the fluid. A simple change such as the increase of the number of channels in a manifold from 6 to 8 has been shown to induce this phenomenon.

In accordance with the present invention there is provided a thermoelectric system comprising a thermoelectric heat pump having at least one manifold attached thereto in which the manifold contains a plurality of channels of substantially singular direction to cause turbulence of the fluid, the thermoelectric heat pump and manifolds having a cross section dimension and minimum number of channels proportional to a thermoelectric heat pump and manifold of dimension of 40mm x 40mm with at least eight (8) channels.

BRIEF DESCRIPTION OF THE DRAWINGS

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

Figure 1 is a schematic perspective view of one embodiment of a thermoelectric system in accordance with the present invention;

Figure 2 is a schematic perspective view of a further embodiment of a thermoelectric system in accordance with the present invention;

Figure 3 is a rear view of a thermoelectric module manifold which can be used in the systems of Figures 1 and 2;

Figure 4 is a cross section through a thermoelectric module with attached manifolds as shown in Figure 3, which can be used in the systems of Figures 1 and 2;

Figure 5 is a front cross-sectional elevation of an embodiment of a submersible pump which can be used in the systems of Figures 1 and 2;

Figure 6 is a side cross sectional elevation of the submersible pump shown in Figure 5;

Figure 7 is a side elevation of a typical conventional thermoelectric module which can be used in the system of Figures 1 and 2;

Figure 8 is a side cross sectional elevation of an embodiment of a novel thermoelectric module which can be used in the systems of Figures 1 and 2; and

Figure 9 is an end cross sectional elevation of the thermoelectric module of Figure 8.

DESCRIPTION OF THE INVENTION

In Figure 1 of the accompanying drawings there is shown a thermoelectric system 10 comprising a thermoelectric module 12 having first and second opposed faces. A respective manifold 14 defining a volume is attached to each face of the thermoelectric module 12.

Each manifold 14 contains an inlet 16 and an outlet 18 as shown in Figure 3. Further, each manifold 14 contains an elongated labyrinthine, zig-zag, spiral or tortuous passageway 20 extending between the inlet 16 and the outlet 18 as shown in Figure 3. The elongated nature of the passageway 20 enhances contact of fluid with the thermoelectric module 12.

The passageway 20 is typically formed by a moulded metal or plastics material to provide the manifold 14 with an outer wall 22 parallel to the corresponding face of the thermoelectric module 12 as shown in Figure 4. The outer wall 22 has extending from it a peripheral wall 24 which extends around the entire periphery of the wall 22. The peripheral wall 24 contains a number of bolt holes 27. The bolt holes 27 allow very small gauge bolts and nuts to hold one manifold 14 to the other manifold 14 on the other side of the thermoelectric module 12. The use of light gauge bolts reduces unwarranted conduction from one side to the other along the bolts.

Within the walls 22 and 24 there is defined, together with the adjacent face of the thermoelectric module 12, a volume 25 containing the passageway 20. The volume 25 has a first partition 26 which extends longitudinally away from the wall 24 at a first end of the volume 25. The first partition 26 extends from a point adjacent the inlet 16 parallel to an adjacent side of the volume 25 partially towards a second end of the volume 25. A second partition 28 is parallel to and spaced from the first partition 26 and extends longitudinally from the wall 24 at a second end of the volume 25 partially towards the first end of the volume 25. This is repeated with a third parallel partition 30 which is similar to the first partition 26 and then 4th, 5th and 6th parallel partitions 32, 34 and 36. Finally, there is a seventh, parallel partition 38 which is similar to the first partition 26 and is located adjacent the outlet 18.

As can be seen in Figure 4 the partitions 26,28,30,32,34,36 and 38 extend from the wall 22 for the same depth as the peripheral wall 24 and engage with the adjacent face of the thermoelectric module 12 with minimal surface area contact with the face. The repeated changes of direction of the channels defined by the partitions ensure that fluid flow through the passageway 20 is turbulent which increases thermal conduction between the fluid and the module face. The preferred number of zig-zagging, spiralling or tortuous fluid channels across a typical (for example) 40mm by 40mm thermoelectric module face has been found by experiment to be approximately eight. Each channel of the passageway 20 is preferably approximately square or half round. Therefore each channel in cross section is close to 5mm x 5mm. However, in reality the channels are usually slightly under 5mm due to the thickness of the channel partitions which are preferably kept to the minimum thickness possible. The number of channels and their depth can be varied to optimise system performance, i.e. when the system is optimised, the heat pumping capacity is at its highest for a given pumping volume and given ambient temperature.

The optimisation of manifold 14 channels is based on a balance between the hydrodynamic impedance of the fluid path through the system (the manifold 14 usually has the highest fluid impedance in the system) versus the fluid pumping capacity of a pump.

The peripheral walls 24 of the manifolds 14 may be sealed to the outer perimeter of the module 12 faces to prevent fluid leakage using known technique such as gaskets "O" rings or silica/rubber cement.

As shown in Figure 1, extending from each inlet 16 there is a respective conduit 40 and extending from each outlet 18 there is a respective conduit 42. One or other of the conduits 40,42 has mounted thereto a pump 44. As shown, each pair of inlet and outlet conduits extends to a remote heat exchanger 46. Each heat exchanger 46 is filled with a fluid which is usually a liquid. Each heat exchanger 46 can be provided with a cooling fan 48. It is possible to design the system so as to make the conduits 40,42 so small as to be unnoticeable, if desired.

In operation of the system 10 of Figure 1, an electrical current (usually direct current but the current can be modified by devices such as proportional current controllers) is applied across the thermoelectric module 12. Simultaneously, the pumps 44 are energised so that liquid commences to be pumped from the heat exchangers 46 through the inlet conduits 40, the manifolds 14, and then through the outlet conduits 42 back to the respective heat exchanger 46. The passage of the electric current through the thermoelectric module 12 causes heat to be pumped from fluid contained in the heat exchanger 46, conduits 40,42 and manifold 14 on one side (inside) to the manifold 14, conduits 40,42 and heat exchanger 46 on another side (outside) so that the refrigerator inside system is cooled and the outside system is heated.

The thermoelectric module 12 may be mounted at a mid-point in a refrigerator wall with the cooling side manifold 14, pump 44, conduits 40,42 and heat exchanger 46 inside of this point and the heating side manifold 14, pump 44, conduits 40,42 and heat exchanger 46 outside of this point. Pumping of liquid through the refrigerator inside system causes heat which is acquired from the interior of the refrigerator via the inside heat exchanger 46 to be carried away from the inside of the refrigerator to the corresponding outside heat exchanger 46 from where the heat is dissipated in known manner.

The thermoelectric system 10 can be operated by employing step control and advantage can be made of the intrinsic non-linear thermal properties of thermoelectric modules and whereby they are at the most efficient when there is a minimal temperature differential across the opposed faces of the module 12. Liquid cooling on each side of the thermoelectric module 12 enables the heat to be readily removed to a remote heat exchanger 46 which can maintain a temperature closer to ambient than conventional solid heat sinks.

In this situation the thermoelectric system 10 described of the present invention can be cycled off when the inside of the refrigerator is at a desired temperature. At this point the fans 48 can be energised so as to bring the outside radiator to a cooler temperature and the inside to a higher temperature (due to the faster absorption of heat from the refrigerator load into the inside heat exchanger) which results in relatively closer inside and outside temperatures (lower temperature differential). Thus, when the thermoelectric system 10 is next re-energised the manifolds 14, pumps 44 and heat exchangers 46 on each side of the thermoelectric module 12 are at a relatively closer temperature differential of the heat transfer fluids and the module 12 itself is closer to a more efficient operating condition.

The ability to cease operation (switch off or cycle off) of the thermoelectric system 10 when the refrigerator achieves a desired inside temperature is enhanced by the fact that the manifolds 14 preferably have small cross-sectional area and small thermal mass and the volume 25 have labyrinthine passageways 20 for fluid flow.

Further, the labyrinthine passageway 20 described above along which the liquid must flow makes it difficult for convection currents to be set up in the liquid after the system 10 has the current removed. Further, when the thermoelectric module 12 is turned off the pumps 44 are also turned off simultaneously so avoiding additional fluid pumping, thereby creating a heat switch or thermal switch effect. Further, the liquid itself is typically a poor conductor of heat, assisting in the heat switch effect, i.e. very little heat transfer takes place from one side of the system to the other side when the module 12 and pumps

44 have their current supply removed.

The liquid or fluid in the system 10 can be typically water on the refrigerator outside and water/glycol, kerosene or methanol on the refrigerator inside. The chemical used on the inside should preferably have high specific heat, low viscosity and ability not to freeze over the thermoelectric module 12 face.

In the embodiment of Figure 2, like reference numerals denote like parts to those found in Figure 1. The thermoelectric system is the same in principle except that one of the heat exchangers 46 is in a tubular enclosure with inside fluid paths surrounded by cooling fins 50 and the other is a pressed metal type 52 which can form a refrigerator wall. In the first, the cooling fan 48 is located adjacent lower ends 54 of the cooling fins 50 and is arranged to rotate about an axis which is aligned with the cooling fins 50 so as to cause air to flow past the cooling fins 50 which causes loss of heat from the cooling fins 50. It is preferable that the flow of air from the fans should be opposite the direction of the flow of the fluid inside the cooling fins 50 so as to maximise efficiency and to create contra flow heat exchangers. In the second pressed type 52, a fan 48 may exist at one end of the refrigerator and circulate air around the inside of the refrigerator. As can be seen in Figure 2, the heat exchanger 52 contains an elongated tube 55 which spirals around the walls of the heat exchanger from the conduit 42 to the conduit 40 or vice versa. Heat is absorbed into the heat exchanger walls and is collected by the fluid in the tube 55 and transported to the module face and eventually dissipated through the heat exchanger on the outside.

It has been found that systems with two sets of thermoelectric modules 12 and attached manifolds 14 offer several advantages. For the same volume of fluid flow, a much higher heat pumping capacity can be attained. Also, run in electrical series the twin module system offers excellent efficiency with high heat pumping capacity and low energy drain. Electronics can be provided to switch the modules between series and parallel to achieve optimum performance for given conditions. Series operation uses relatively low power and is efficient in normal operating conditions whereas parallel operation uses relatively high power but is only necessary where it is desired to have low inside refrigerator temperature in high ambient temperature conditions.

A twin module system is shown in Figure 2 in which the outlet of each manifold 14 is connected to the inlet of each contiguous manifold 14 by a tube 56.

The pumps 44 used in the present invention to circulate the fluid can take many forms.

However, a novel type of brushless, submersible, centrifugal pump which has been found to be particularly effective is illustrated in Figures 5 and 6. The pump 78 is illustrated in Figures 5 and 6 comprises a rear casing 80 and a bearing shaft 82 mounted to a wall of the rear casing 80. A number of electrical coils 84 are disposed about the bearing shaft 82 and neither shaft 82 nor coils 84 are arranged to rotate but are fixed relative to the rear casing 80.

The pump 78 further comprises a magnet housing 86 and a moulded impeller 88 and a bearing 90. The magnetic housing 86, impeller 88 and bearing 90 are preferably formed from one part by moulding or machining. A circular magnet 92 (or plurality of spaced magnets arranged in a circle) is mounted in the magnet housing 86 outwardly of the coils. Electrical wires 94 extend through the rear casing 80 in sealed manner and are connected to the coils 84.

The electrical wires 94 connect coils 84 to a set of electronics which energise the coils 84 in such a manner as to cause the impeller 88 and the magnet 92 to rotate around the coils 84 in known manner. To facilitate this, the impeller 88 and the magnet housing 86 are provided with the bearing 90 which is arranged for rotation around the stationary bearing shaft 82. In this realisation the bearing 90 is the sole load bearing mounting for the impeller 88 and the magnet housing 86.

In operation, liquid is located in an inlet conduit 96 partly formed by a front outer casing 112. Energisation of the coils 84 causes rotation of the magnet 92 around the coils 84 and thus rotation of the impeller 88. In this way, the impeller 88 is caused to rotate and this induces the liquid to be displaced sideways in the direction of the arrow 108. Thus, a liquid flow is created in the conduit.

A preferred form of impeller 88 is shown in Figure 5. As shown the impeller 88 comprises a general circular disc 100 which has a centre 102 which is cut away. A plurality of elongated cut outs 104 extend outwardly from the cut away centre 102. Rotation of the impeller 88 shown in Figure 5 causes liquid to be displaced to an outlet conduit 106 in the direction of the arrow 108 as shown in Figure 6. Preferably, the outlet conduit 106 has an inner curved portion 110 of progressively increasing cross section towards the outer portion of the conduit 106 in the direction of the curve as can be seen in Figure 5. This configuration is shown as a scroll pattern outlet sweep. Although it is possible to use an outside motor connected to the coolant system via a sealed shaft, this arrangement is not entirely satisfactory due to the possibility of leaks developing if the seals wear.

The heat exchangers 46 that can be successfully incorporated in the present invention can take many forms. The choice is based on heat exchange capability versus cost. Preferred types include copper automotive types, extruded or pressed sheet aluminium types and assembled types constructed of thin aluminium sheet/foil fins pushed over copper/aluminium tubes.

A particularly successful application of the thermoelectric system of the present invention is to utilise very simple outside heat exchangers which may be no more elaborate than a metal tube, for example, which can be immersed in sea/fresh water. The heat exchanger is then cooled by the body of water which is, in the case of the ocean, an infinite heat exchanger itself. The system is therefore also very efficient for marine applications.

A conventional thermoelectric module 120 which may be used in the present invention is illustrated in Figure 7. The module 120 comprises a pair of outer, parallel plates 122 which are thermally conductive but electrical insulators. The plates 122 have outer surfaces 128 which are the module faces. With the plates 122 there is a row of spaced thermocouples 124. The first and second thermocouples 124 at the left as can be seen in Figure 7 are electrically interconnected by a conductive plate connector 126 at a first end thereof. The second and third thermocouples 124 from the left as seen in Figure 7 are electrically interconnected by a conductive plate connector 126 at a second end thereof. The alteration of the ends of interconnection of the adjacent thermocouples 124 is repeated across the entire row so that there is an electrically conductive plate across the entire row of thermocouples 124. The plate connectors 126 are also connected to the outer plates 122 in heat conductive manner.

A form of novel thermoelectric module which is particularly efficacious in the context of the present invention is illustrated in Figures 8 and 9.

In the embodiment of Figures 8 and 9, there is provided a plurality of spaced P and N thermocouples 130 extending in a row. The thermocouple 130 row is located between two housings each having an outer side wall 134 and two end walls 136. Further, each housing contains an inner side wall 132 formed of plastics material and apertured to hold thermocouple connectors in position as will be described. The walls 132 are kept as thin as possible to minimise coverage of the thermocouple connectors.

The side walls 134 are spaced apart from the thermocouple 130 row while the end walls 136 are connected to ends of the thermocouple 130 row. Further, the side walls 134 and end walls 136 define inlet conduits 138, outlet conduits 140 and intermediate coolant passages 142.

As can be seen, the left most thermocouple 130 is connected at a first end by a block of electrically and thermally conductive material 144 such as copper, to the first end of the next adjacent thermocouple 130. The next adjacent thermocouple 130 is connected at a second end by a block of electrically and thermally conductive material 144 to a second end of the next adjacent thermocouple 130 to the right as seen in Figure 8. This arrangement is repeated right across the thermocouple 130 row. In this way, there is an electrically conductive path across the thermocouple 130 row extending from one end thereof through each electrically conductive block 144 and each thermocouple 130 in turn. Further, as described above each electrically and thermally conductive block 144 is held in position by being located in an aperture in a side wall 132.

In known manner, the dissimilar electrically conductive materials of the P and N thermocouples 130 gives rise to the Peltier effect via the junctions or connector blocks 144 when an electric current is applied. This causes heat to be pumped from one side of the thermocouple 130 row to the other.

In the arrangement shown in Figures 8 and 9, liquid is always present in the inlets 138, outlets 140 and fluid passageway 142. In accordance with the present invention, when electric current is applied to the thermocouples 130, the pumps 44 are preferably simultaneously energised to cause the liquid to flow across both sides of the thermocouple 130 row.

The liquid is circulated to the remote heat exchangers 46 as described above to transfer heat. The electrically non-conductive liquid directly contacts the electrically conductive blocks 144 so that there are no solid-solid interfaces such as are found between thermoelectric modules and solid heat sinks in prior art devices. This reduces inefficiencies encountered in prior art devices.

Between the two walls 132 and surrounding the thermocouples 130 there is a gap 146. This gap or void 146 may be filled with air or foam. More preferably, the gap 146 may be under vacuum or be filled with aerogel. The advantage of the aerogel or vacuum is that they reduce transfer of heat by conduction, convection and radiation between the hot and cold sides of the thermoelectric module.

Most importantly, the advantage of the module shown in Figures 8 and 9 over the system otherwise described by this invention but used with conventional thermoelectric modules is that the liquid can flow directly over the enlarged thermocouple connectors 144. The connectors 144 themselves can increase the surface area of thermal contact by up to six times or more over conventional thermoelectric module connectors as shown in Figure 7. Furthermore, conventional thermoelectric modules have non-electrically conductive faces soldered onto the connectors before the coolant can make contact with the module face. There are significant losses in the solder and ceramic by way of thermal impedance that are avoided in the module shown in Figure 8.

Modifications and variations such as would be apparent to a skilled addressee are deemed within the scope of the present invention. For example, the thermoelectric system of the present invention can be used in reverse mode to heat the inside of a container such as an incubator or food warmer.

The claims defining the invention are as follows:-

1. A thermoelectric system comprising at least one thermoelectric heat pump having a plurality of thermocouples disposed between first and second opposed thermally conductive outer faces, the first outer face being relatively cool and the second outer face being relatively hot in use, a first and second manifold defining a volume being attached to each opposed outer face of the thermoelectric heat pump, respectively, each manifold having an outer wall spaced from the thermoelectric heat pump and side walls abutting the respective first and second outer faces thereby defining an open face, the respective side walls and outer wall and outer face thereby defining the volume, each manifold having a fluid inlet and fluid outlet so that, in use, fluid flows through the manifolds, wherein each outer face directly contacts the fluid flowing through the respective manifolds, first and second heat exchangers, the first manifold being connected to the first heat exchanger, and the second manifold being connected to the second heat exchanger, and the first and second fluid pumps being provided for circulating fluid as a liquid between the manifolds and the heat exchangers, wherein the first manifold attached to the cold outer face is connected to the first fluid pump and the first heat exchanger and the second manifold attached to the hot outer face is connected to the second fluid pump and the second heat exchanger so that fluid from the first manifold attached to the cold outer face of the thermoelectric heat pump is circulated through the first heat exchanger by the first fluid pump and fluid from the second manifold attached

to the hot outer face of the thermoelectric heat pump is circulated through the second heat exchanger by the second fluid pump, wherein each manifold contains means defining an elongated passageway so as to enhance contact of fluid with the thermoelectric heat pump and each manifold contains a plurality of partitions to define a plurality of channels of substantially singular direction to cause turbulence of the fluid, the thermoelectric heat pump and manifold having a cross section dimension and minimum number of channels proportional to a thermoelectric heat pump and manifold of dimension of 40mm x 40mm with at least eight (8) channels.

2. A thermoelectric system according to claim 1 wherein a plurality of the thermoelectric heat pumps are arranged side by side.

3. A thermoelectric system according to claim 1 or 2, wherein each manifold contains a plurality of generally parallel partitions which extend longitudinally from a wall of the manifold partially towards an opposed wall, adjacent partitions extending from opposite walls so as to define a lalbyrinthine fluid passageway which causes fluid to undergo a plurality of reversals of direction in passing from the inlet to the outlet.

4. A thermoelectric system according to any one of claims 1 to 3, wherein a respective conduit extends from each inlet and outlet to a remote heat exchanger and the fluid pump means for each manifold is located in one of the conduits.

5. A thermoelectric system according to any one of claims 1 to 4, wherein at least one heat exchanger contains a cooling fan.

6. A thermoelectric system according to any one of claims 1 to 5, wherein as an electric current is applied across the or each thermoelectric heat pump, each fluid pump is automatically energised.

7. A thermoelectric system according to any one of claims 1 to 6, wherein the system is arranged to be cycled off when a desired condition is achieved.

8. A thermoelectric system according to claim 7, wherein the or each fluid pump is automatically arranged to be de-energised when the system is cycled off.

9. A thermoelectric system according to any one of claims 1 to 8, wherein the system is so arranged to act as a heat switch when the or each thermoelectric heat pump is de-energised.

10. A thermoelectric system according to any one of claims 1 to 9, wherein the or each thermoelectric heat pump is electrically connected to be in series or parallel as desired.

11. A thermoelectric system according to claim 1, wherein there is a plurality of the thermoelectric heat pumps and each cool outer face faces in one direction and each hot outer face faces in an opposite direction.

12. A thermoelectric system according to any one of claims 1 to 11, wherein there are a plurality of the thermoelectric heat pumps with attached manifolds and wherein the manifolds attached to the hot outer faces of the thermoelectric heat pumps are fluidly interconnected so that fluid flows through a plurality of manifolds and is subsequently circulated through the first heat exchanger by the first fluid pump, and the manifolds attached to the cold outer faces of the thermoelectric heat pumps are fluidly interconnected so that fluid flows through a plurality of manifolds and is subsequently circulated through the second heat exchanger by the second fluid pump.

13. A thermoelectric system according to any one of claims 1 to 12, wherein each manifold is formed of a molded plastics material and contains a plurality of partitions which engage a face of the thermoelectric heat pump with minimal surface area contact.

14. A thermoelectric system according to any one of claims 1 to 13, wherein the electrical current to the or each thermoelectric heat pump can be reversed so that the heat pump can operate in the reverse direction to enable it to be used as both a cooling

and heating system.

15. A thermoelectric system comprising a plurality of thermoelectric heat pumps arranged side by side and each having first and second opposed outer faces, each first outer face being relatively cool and each second outer face being relatively hot in use, each cool outer face facing in one direction and each hot outer face facing in an opposite direction, a respective manifold attached to each opposed face of each thermoelectric heat pump, each manifold defining a volume and an outer wall spaced from the thermoelectric heat pump and side walls abutting the respective first and second outer faces thereby defining an open face, the respective side walls and outer wall and outer face thereby defining the volume, each manifold having a fluid inlet and fluid outlet so that in use fluid flows through each manifold wherein each outer face directly contacts the fluid flowing through the respective manifold, the manifolds being connected to heat exchange means and fluid pump means being provided for circulating fluid between the manifolds at the fluid inlets and outlets and the heat exchange means, wherein the manifolds on the cold outer faces are fluidly connected to a first fluid pump and a first heat exchanger and the manifolds on the hot outer faces are fluidly connected to a second fluid pump and a second heat exchanger so that fluid from the manifolds attached to the cold outer faces of the thermoelectric heat pumps is circulated through the first heat exchanger by the first fluid pump and fluid from the manifolds attached to the hot outer faces of the thermoelectric heat pumps is circulated through the second heat exchanger

by the second fluid pump, wherein each manifold contains means defining an elongated passageway so as to enhance contact of fluid with the thermoelectric heat pump and each manifold contains a plurality of partitions to define a plurality of channels of substantially singular direction to cause turbulence of the fluid, the thermoelectric heat pump and manifold having a cross section dimension and minimum number of channels proportional to a thermoelectric heat pump and manifold of dimension of 40mm x 40mm with at least eight (8) channels.

16. A thermoelectric system comprising a plurality of thermoelectric heat pumps arranged side by side, at least two of the thermoelectric heat pumps having first and second opposed outer faces, each first outer face being relatively cool and each second outer face being relatively hot in use, each cool outer face facing in one direction and each hot outer face facing in an opposite direction, a respective manifold is attached to each opposed face of the at least two thermoelectric heat pumps, each manifold defining a volume and having an outer wall spaced from the thermoelectric heat pump and side walls abutting the respective first and second outer faces thereby defining an open face, the respective side walls and outer wall and outer face thereby defining the volume, each manifold having a fluid inlet and fluid outlet so that in use fluid flows through each manifold wherein each outer face directly contacts the fluid flowing through the respective manifold, the manifolds being connected to first and second heat exchangers and fluid pumps being provided for circulating fluid between the manifolds

and the heat exchangers, wherein the manifolds on the cold outer faces are fluidly connected to the first fluid pump and first heat exchanger and the manifolds on the hot outer faces are fluidly connected to the second fluid pump and the second heat exchanger so that fluid from the manifolds attached to the cold outer faces of the thermoelectric heat pumps is circulated through the first heat exchanger by the first fluid pump and fluid from the manifolds attached to the hot outer faces of the thermoelectric heat pumps is circulated through the second heat exchanger by the second fluid pump, wherein each manifold contains means defining an elongated passageway so as to enhance contact of fluid with the thermoelectric heat pump and each manifold contains a plurality of partitions to define a plurality of channels of substantially singular direction to cause turbulence of the fluid, the thermoelectric heat pump and manifold having a cross section dimension and minimum number of channels proportional to a thermoelectric heat pump and manifold of dimension of 40mm x 40mm with at least eight (8) channels.

17. A thermoelectric system according to claim 1, wherein each passageway has a cross section of 5mm or less.

18. A thermoelectric system according to claim 17, wherein each manifold contains a plurality of partitions to define a plurality of channels of substantially singular direction of the passageway wherein there are at least eight channels to cause turbulence of the fluid.

19. A thermoelectric system according to claim 1, wherein each manifold contains a plurality of partitions to define a plurality of channels of substantially singular direction of the passageway wherein there are at least eight channels to cause turbulence of the fluid.

20. A thermoelectric system according to claim 1, wherein each manifold contains a plurality of generally parallel partitions which extend longitudinally from a wall of the manifold towards an opposed wall, the partitions producing a zig-zag passageway.

21. A thermoelectric system according to claim 1, wherein each manifold contains a plurality of generally parallel partitions which extend longitudinally from a wall of the manifold towards an opposed wall, the partitions producing a spiral passageway.

22. A thermoelectric system according to claim 1, wherein each manifold contains a plurality of partitions which extend longitudinally from a wall of the manifold, the partitions producing a tortuous passageway.

23. A thermoelectric system comprising:

at least one thermoelectric heat pump having first and second opposed thermally conductive outer faces, the first outer face being relatively cool and the second outer face being relatively hot in use;

at least one manifold defining a volume being attached to either or both opposed first and second outer faces of the thermoelectric heat pump, respectively, the or each manifold having a fluid inlet and fluid outlet so that, in use, fluid flows through the or each manifold; and

the or each manifold includes an outer wall spaced from the thermoelectric heat pump and side walls abutting the respective outer face thereby defining an open face with the side walls and outer wall and outer face thereby defining the volume wherein at least one outer face directly contacts the fluid flowing through the respective manifold, wherein said at least one manifold contains an elongated passageway extending therethrough to enhance contact of fluid with the thermoelectric heat pump and contains a plurality of partitions to define a plurality of channels of substantially singular direction to cause turbulence of the fluid, the thermoelectric heat pump and manifold having a cross section dimension and minimum number of channels proportional to a thermoelectric heat pump and manifold of dimension of 40mm x 40mm with at least eight (8) channels.

24. A system set forth in claim 23, wherein the or each manifold includes an outer wall spaced from the thermoelectric heat pump and side walls abutting the respective outer face thereby defining an open face with the side walls and outer wall and outer face thereby defining the volume wherein th- respective outer face directly contacts the fluid flowing through the respective manifold.

25. A system as set forth in claim 23, wherein said at least one manifold includes an elongated passageway extending between the fluid inlet and fluid outlet, the elongated passageway having a cross section of 5mm or less.

26. A thermoelectric system comprising:

at least one thermoelectric heat pump having first and second opposed thermally conductive outer faces, the first outer face being relatively cool and the second outer face being relatively hot in use;

at least one manifold defining a volume being attached to either or both opposed outer faces of the thermoelectric heat pump, respectively, the or each manifold having a fluid inlet and fluid outlet so that, in use, fluid flows through the or each manifold; and the or each manifold contains an elongated passageway extending therethrough to enhance contact of fluid with the thermoelectric heat pump, and contains a plurality of partitions to define a plurality of channels of substantially singular direction to cause turbulence of the fluid, the thermoelectric heat pump and manifold having a cross section dimension and minimum number of channels proportional to a thermoelectric heat pump and manifold of dimension of 40mm x 40mm with at least eight (8) channels.

27. A thermoelectric system comprising:

at least one thermoelectric heat pump having first and second opposed outer faces, the first outer face being relatively cool and the second outer face being relatively hot in use;

at least one manifold defining a volume being attached to either or both opposed outer faces of the thermoelectric heat pump, respectively, the or each manifold having a fluid inlet and fluid outlet so that, in use, fluid flows through the or each manifold; and

at least one of the said manifolds including an elongated passageway extending between the fluid inlet and fluid outlet, the elongated passageway having a cross section of 5mm or less so as to cause turbulence of the fluid and the at least one manifold contains a plurality of partitions to define a plurality of channels of substantially singular direction to cause turbulence of the fluid, the thermoelectric heat pump and manifold having a cross section dimension and minimum number of channels proportional to a thermoelectric heat pump and manifold of dimension of 40mm x 40mm with at least eight (8) channels.

28. A system as set forth in claim 27, wherein said manifolds each include an outer wall spaced from the thermoelectric heat pump and side walls abutting the respective first and second outer faces thereby defining an open face, the respective side walls and outer wall and outer face thereby defining the volume wherein each outer face directly contacts the fluid flowing through the respective manifold.

29. A system as set forth in claim 27, further including a heat exchanger fluidly connected to a manifold for exchanging heat with fluid circulating between the said manifold and heat exchanger.

30. A system as set forth in claim 29, further including first and second fluid pumps wherein the first manifold is connected to the first fluid pump and the first heat exchanger for circulated fluid, and the second manifold is connected to the second fluid pump and the second heat exchanger for circulating fluid therebetween.

31. A thermoelectric system comprising:

at least one thermoelectric heat pump having first and second opposed outer faces, the first outer face being relatively cool and the second outer face being relatively hot in use;

at least one manifold defining a volume being attached to either or both opposed outer faces of the thermoelectric heat pump, respectively, the or each manifold having a fluid inlet and fluid outlet so that, in use, fluid flows through the or each manifold; and

first and second heat exchangers, a first manifold being connected to the first heat exchanger, and a second manifold being connected to the second heat exchanger for circulating fluid between the or each manifold and the heat exchangers wherein a manifold attached to the cold outer face is connected to the first heat exchanger and a manifold attached to the hot outer face is connected to the second heat exchanger so that fluid from a manifold attached to the cold outer face of the thermoelectric heat pump is circulated through the first heat exchanger and fluid from a manifold attached to the hot outer face of the thermoelectric heat pump is circulated through the second heat exchanger; and

at least one of the manifolds includes an elongated passageway extending therethrough, the elongated passageway having a cross section of 5mm or less and the at least one manifold contains a plurality of partitions to define a plurality of channels of substantially singular direction to cause turbulence of the fluid, the thermoelectric heat pump and manifold having a cross section dimension and minimum number of channels proportional to a thermoelectric heat pump and manifold of dimension of 40mm x 40mm with at least eight (8) channels.

32. A system as set forth in claim 31, wherein the at least one manifold contains a plurality of generally parallel partitions which extend longitudinally from a wall of the manifold partially towards an opposed wall, adjacent partitions extending from opposite walls so as to define a labyrinthine fluid passageway which causes fluid to undergo a plurality of reversals of direction in passing from the inlet to the outlet.

33. A system as set forth in claim 31, wherein the at least one manifold contains a plurality of generally parallel partitions which extend longitudinally from a wall of the manifold toward an opposed wall, the partitions defining a zig-zag passageway.

34. A system as set forth in claim 31, wherein the at least one manifold contains a plurality of generally parallel partitions which extend longitudinally from a wall of the manifold toward an opposed wall, the partitions inducing a spiral fluid flow.

35. A system as set forth in claim 31, wherein the at least one manifold contains a plurality of partitions which extend longitudinally from a wall of the manifold, the partitions producing a tortuous passageway.

36. A system as set forth in claim 31, wherein the at least one manifold each includes an outer wall spaced from the thermoelectric heat pump and side walls abutting a respective outer face thereby defining an open face, the respective side walls and outer wall and outer face thereby defining the volume wherein the respective outer face directly contacts the fluid flowing through the respective manifold.

37. A system as set forth in claim 31, further including at least one fluid pump wherein a first manifold is connected to a first fluid pump and a first heat exchanger for circulating fluid therebetween, and a second manifold is connected to a second fluid pump and a second heat exchanger for circulating fluid therebetween.

38. A thermoelectric system comprising:

at least one thermoelectric heat pump having first and second opposed thermally conductive outer faces, the first outer face being relatively cool and the second outer face being relatively hot in use;

a manifold defining a volume being attached to at least one opposed outer face of the thermoelectric heat pump, respectively, the or each manifold having a fluid inlet and fluid outlet so that, in use, fluid flows through the or each manifold;

first and second heat exchangers, a first manifold being connected to the first heat exchanger, and a second manifold being connected to the second heat exchanger;

first and second fluid pumps being provided for circulating fluid as a liquid between the manifolds and the heat exchangers wherein a manifold attached to the cold outer face is connected to the first fluid pump and the first heat exchanger and a manifold attached to the hot outer face is connected to the second fluid pump and the second heat exchanger so that fluid from a manifold attached to the cold outer face of the thermoelectric heat pump is circulated through the first heat exchanger by the first fluid pump and fluid from a manifold attached to the hot outer face of the thermoelectric heat pump is circulated through the second heat exchanger by the second fluid pump; and

the or each manifold containing an elongated passageway extending therethrough to enhance contact of fluid with the thermoelectric heat pump, at least one of the manifolds containing a plurality of partitions to define a plurality of channels of substantially singular direction to cause turbulence of the fluid, the thermoelectric heat pump and the or manifold having a cross section dimension and minimum number of channels proportional to a thermoelectric heat pump and manifold of dimension of 40mm x 40mm with at least eight channels.

39. A system as set forth in claim 38, wherein the at least one manifold includes an outer wall spaced from the thermoelectric heat pump and side walls abutting a respective outer face thereby defining an open face, the respective side walls and outer wall and outer face thereby defining the volume wherein the respective outer face directly contacts the fluid flowing through the respective manifold.

40. A thermoelectric system substantially as hereinbefore described with reference to the accompanying drawings.

Dated the 3rd day of May 1996

Hydrocool Pty Ltd
by their Patent Attorneys
LORD & COMPANY
PERTH, WESTERN AUSTRALIA

11731/92

FIGURE 1

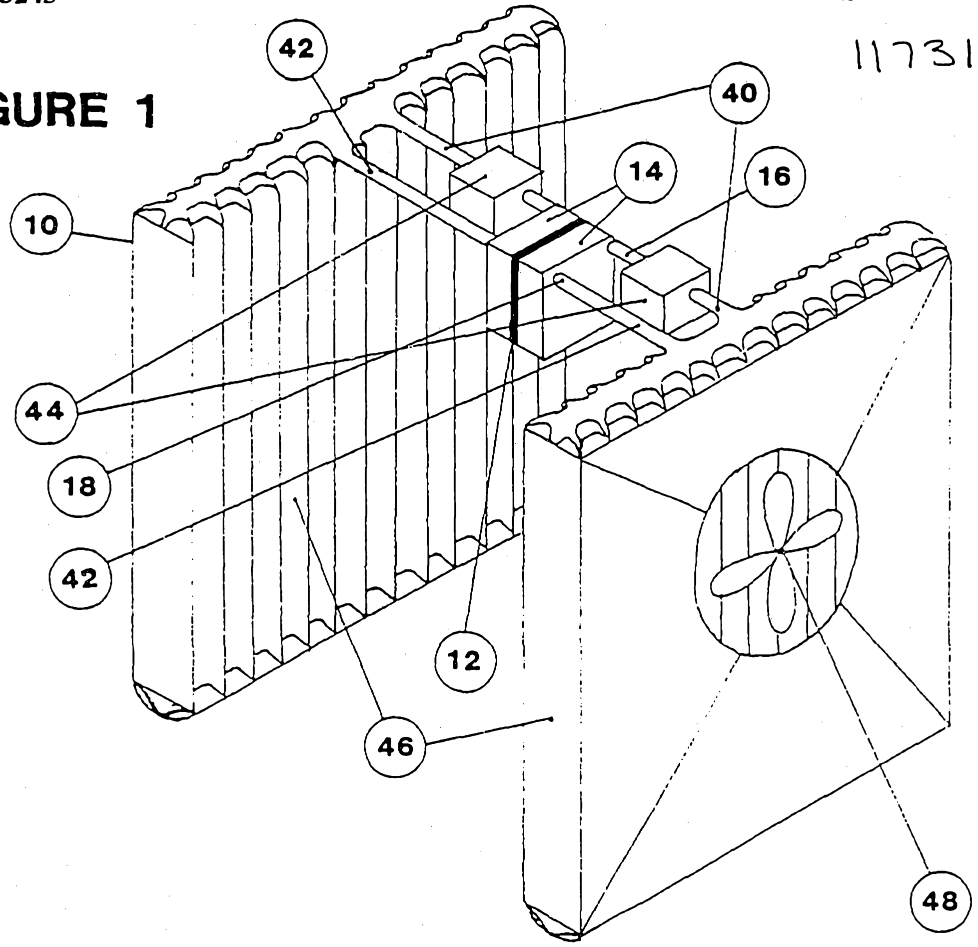
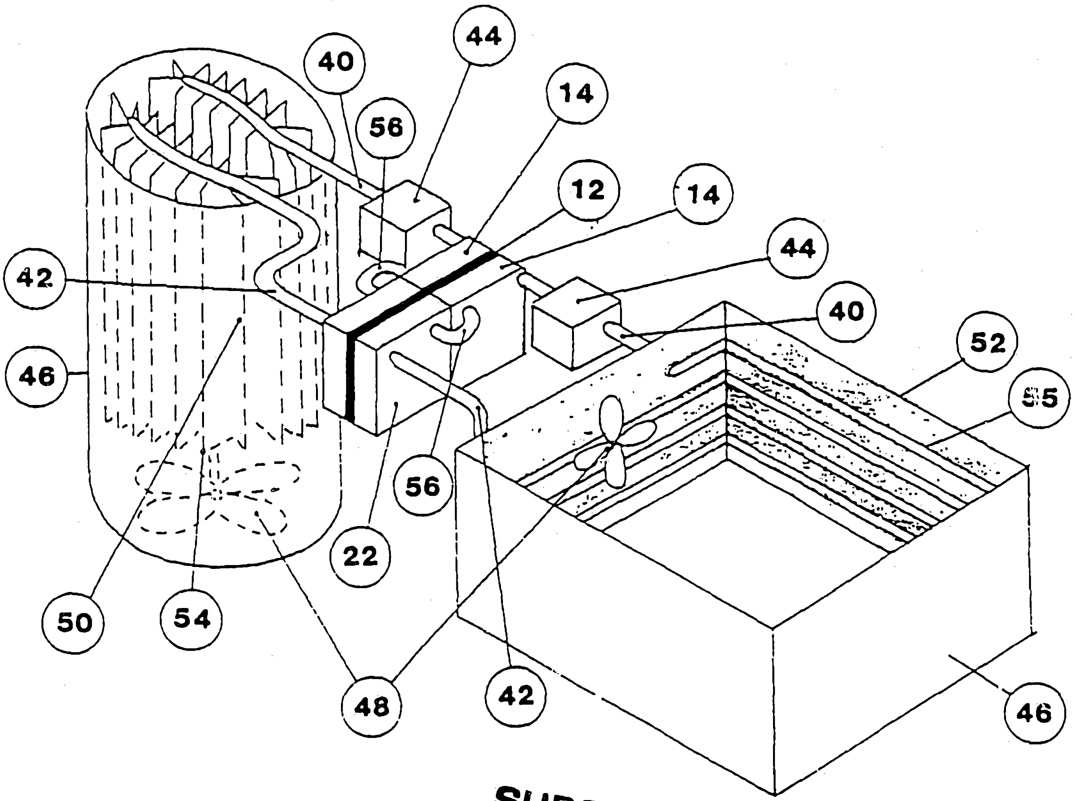


FIGURE 2



SUBSTITUTE SHEET

FIGURE 3

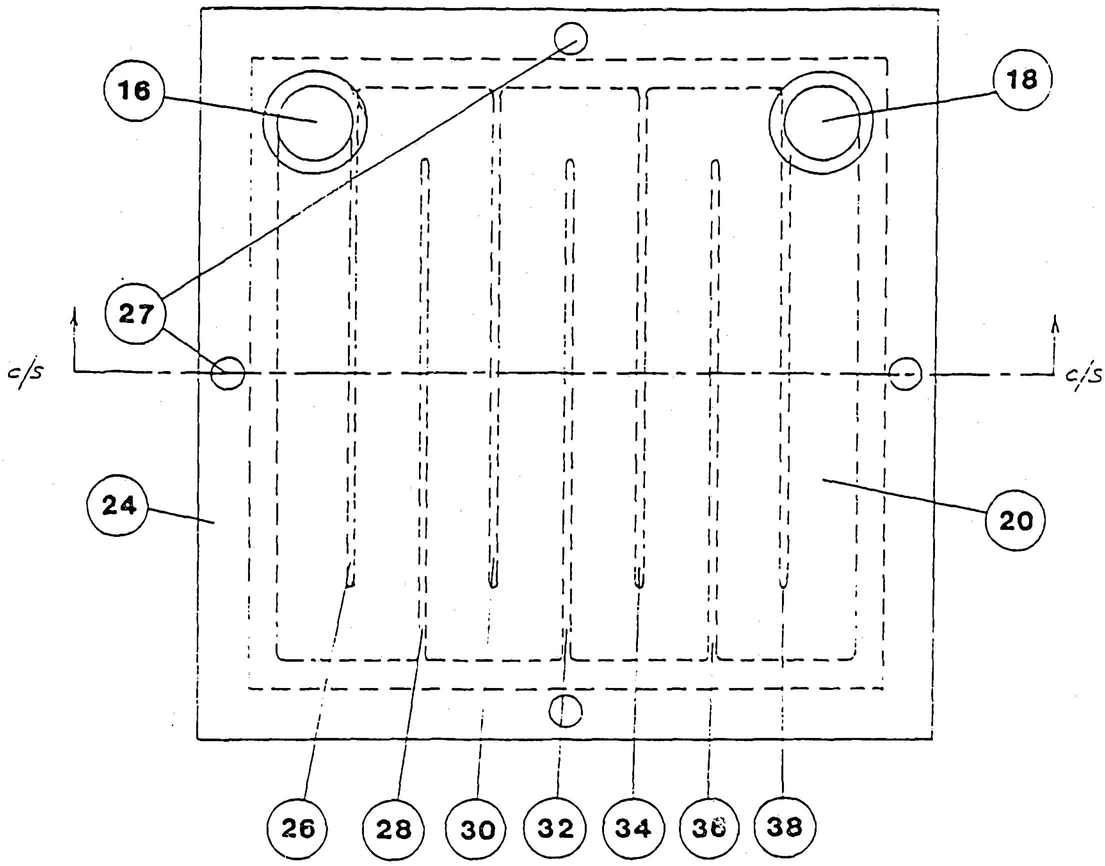


FIGURE 4

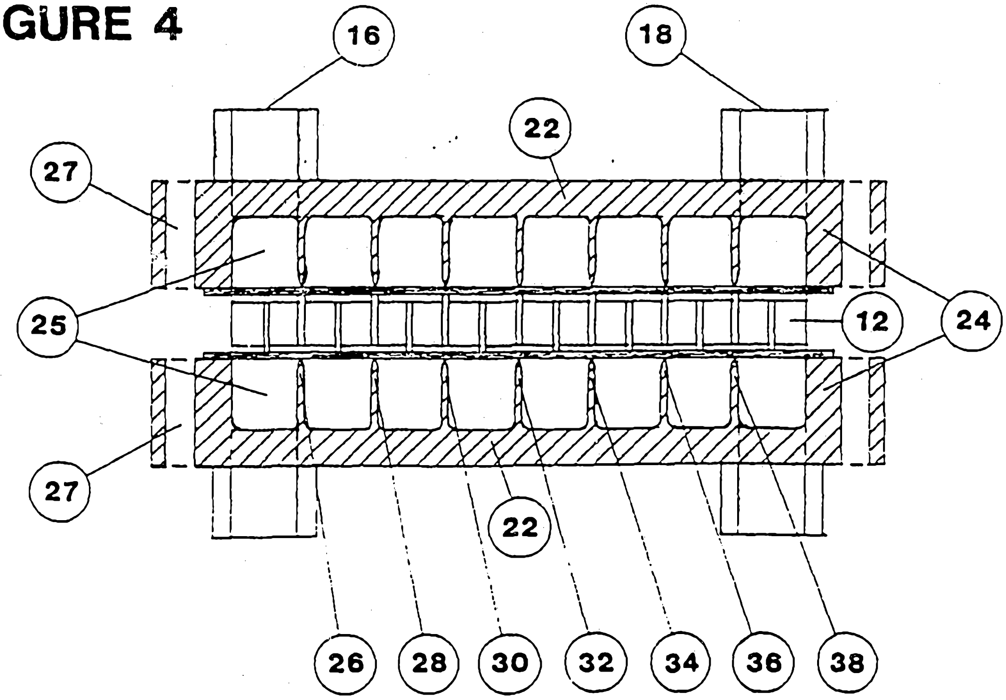


FIGURE 5

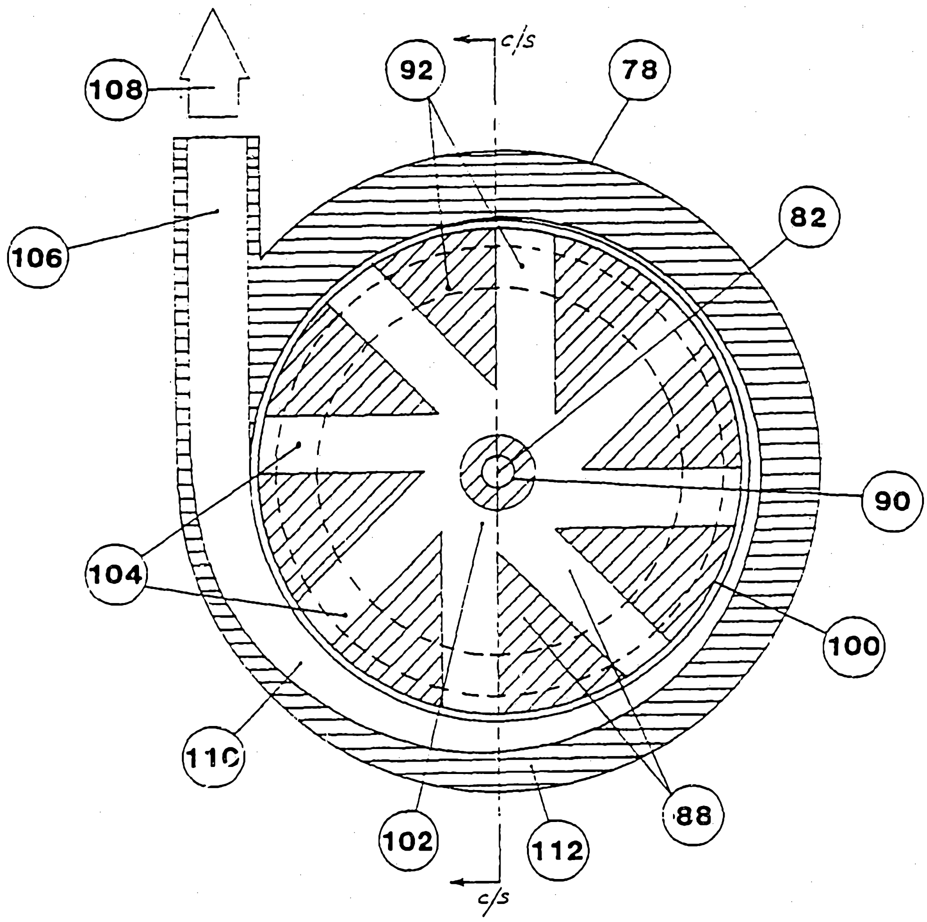


FIGURE 6

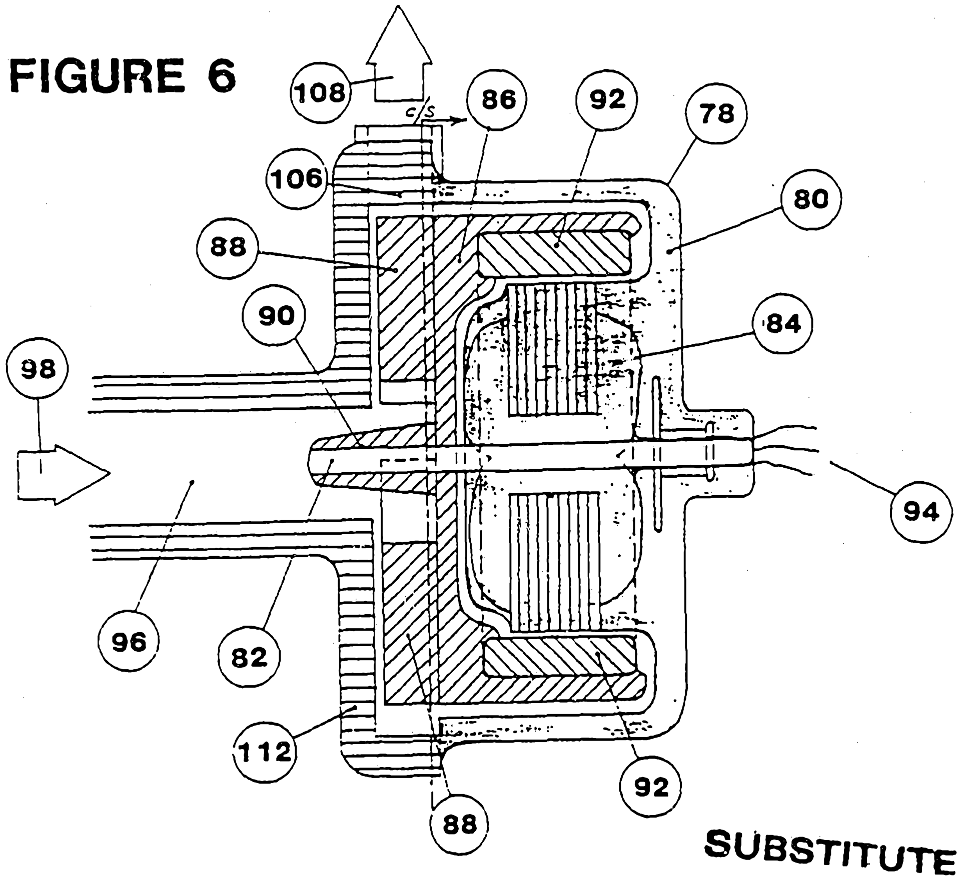


FIGURE 7

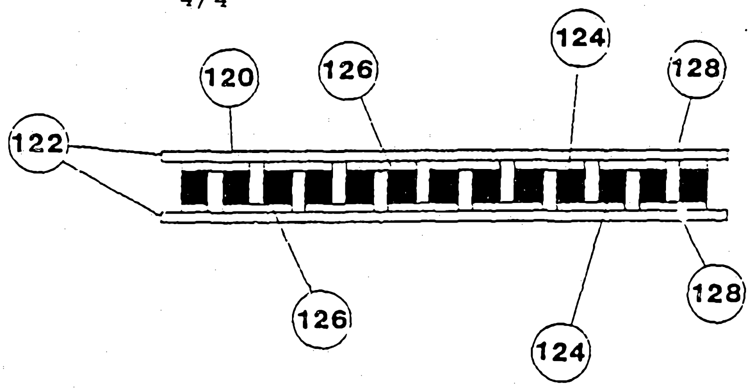


FIGURE 8

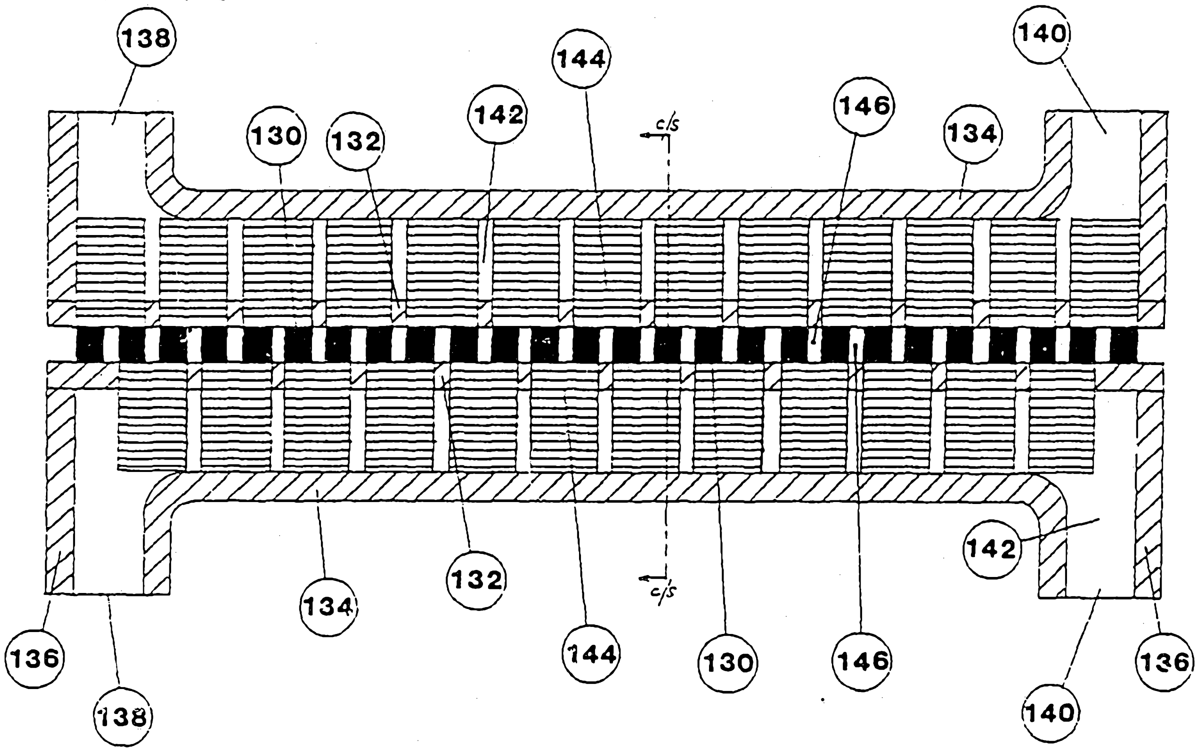
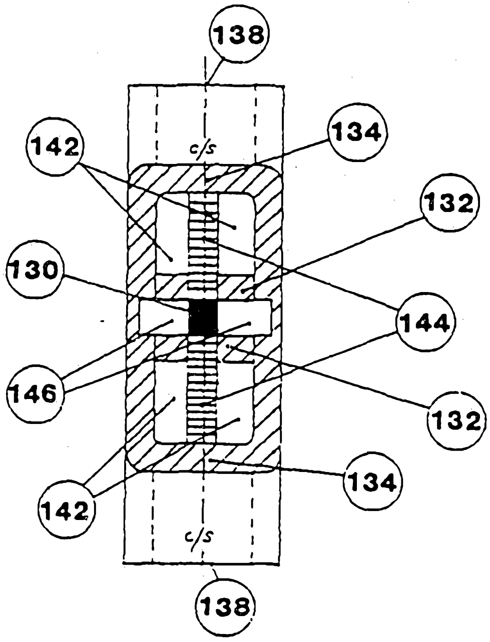


FIGURE 9



International Application No. PCT/AU 92/00008

INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

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

Int. Cl.[5] F25B 21/02, H01L 35/28, F04D 13/02, 13/08, H02K 7/14, 21/22

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	F25B 21/02, F04D 13/08, H02K 21/22

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category*	Citation of Document, [11] with indication, where appropriate of the relevant passages [12]	Relevant to Claim No [13]
X	US,A, 4829771 (KOSLOW et all) 16 May 1989 (16.05.89) See claims 1,3,11 and Figures 2,3 and 4	(1-5,11)
X	GB,A, 868029 (THE GENERAL ELECTRIC COMPANY LTD) 17 May 1961 (17.05.61) See page 2 lines 10-18 and the Figure	(1,5)
A	FR,A, 1299540 (SOCIETE ALSACIENNE DE CONSTRUCTIONS MECHANIQUES) 18 June 1962 (18.06.62) See Figure 1	
A	US,A, 3111813 (BLUMENTRITT) 26 November 1963 (26.11.63) See Figure 2	
	(continued)	

* Special categories of cited documents : [10]

"A" Document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior t the international filing date but later than the priority date claimed

"T" Later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
14 April 1992 (14.04.92)	21 April 1992 (21.04.92)
International Searching Authority	Signature of Authorized Officer
AUSTRALIAN PATENT OFFICE	O.L. HAGGAR OL Haggar

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

Y	AU,B, 26396/63 (267755) (PLEUGER) 16 July 1964 (16.07.64) See pages 2 & 3 and Figure 1	(12)
Y	AU,A, 5473/66 (BRUCE PEEBLES INDUSTRIES LIMITED) 16 November 1967 (16.11.67) See Figure 1 and page 2	(12)
Y	GB,A, 2159002 (PAPST-MOTOREN GMBH & CO KG) 20 November 1985 (20.11.85) See Figure 1 and page 1	(12)
Y	EP,A1, 0043162 (IMO AB JONKOPINGS MEKANISKA WERKS) 6 January 1982 (06.01.82) See page 4 and the Figure	(12)

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim numbers ..., because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers ..., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers ..., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4a

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

Claims 1 to 11 are directed to a thermoelectric system, claim 12 is directed to a submersible centrifugal pump, and claim 13 is directed to a thermoelectric module.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

   1 to 12

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☒ No protest accompanied the payment of additional search fees.