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(54) Title: AN ALUMINIUM-AIR CELL, AN ALUMINIUM-AIR BATTERY AND A MOTOR UNIT COMPRISING AN ELECTRIC MOTOR AND AN ALUMINIUM- AIR BATTERY

(57) Abstract: In a first aspect the present invention relates to an aluminium-air cell and to an aluminium-air battery comprising a plurality of the aluminium-air cells. In a second aspect the present invention relates to a motor unit which comprises the aluminium-air cell or the aluminium-air battery of the invention along with an electric motor. An aluminium-air cell (10) comprises: a casing (12) and within the casing: an air cathode (23); an electrode (27) of aluminium or aluminium alloy spaced from the air cathode; an electrolyte chamber (45) defined between the air cathode and the electrode; an electrolyte liquid; a reservoir cavity (36) separate from the electrolyte chamber for storing the electrolyte liquid; a rotatable shaft (15); a delivery conduit (37) connecting the reservoir cavity and the electrolyte chamber; and an impeller device (20) driven by the rotatable shaft to draw the electrolyte liquid out of the reservoir and pump the drawn electrolyte liquid through the delivery conduit into the electrolyte chamber.

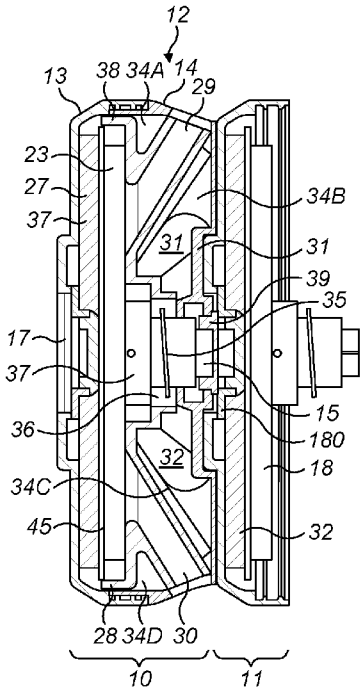

FIG. 1

WO 2016/178017 A1

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AN ALUMINIUM-AIR CELL, AN ALUMINIUM-AIR BATTERY AND A MOTOR UNIT COMPRISING AN ELECTRIC MOTOR AND AN ALUMINIUM-AIR BATTERY

In a first aspect the present invention relates to an aluminium-air cell and to an aluminium-air battery comprising a plurality of the aluminium-air cells. In a second aspect the present invention relates to a motor unit which comprises the aluminium-air cell or the aluminium-air battery of the invention along with an electric motor.

Aluminium-air cells comprise a consumable aluminium electrode and a liquid electrolyte such as sodium hydroxide or potassium hydroxide. Aluminium-air cells are not rechargeable and therefore the cells or at least the aluminium electrodes parts of them must be constructed to be replaceable.

In general aluminium-air cells face the following technical problems. First, the reaction of the aluminium electrode with the electrolyte forms aluminium hydroxide, which can in turn form a gel by attracting water molecules and the gel can clog up the aluminium electrode and the air cathode. Secondly, the aluminium electrode can corrode in the presence of the electrolyte and the surface of the electrode then becomes pitted and the electrode degraded . Since the aluminium electrode is consumed during use, care must be taken to maintain the connection of the electrodes to an external circuit, despite the consumption of the electrode. During the operation of the cell, hydrogen is produced and provision must be made to allow venting of this hydrogen to the outside of the cell. Heat management is also a technical issue and in the past external cooling circuit systems have been required in order to cool the cell during operation, which reduces the efficiency of the cell, since some of the output of the cell must be used by the cooling systems. Also there is a requirement for powered gel separation and for a powered system for allowing hydrogen escape in several prior art systems, which again takes power from the cell.

The above-noted technical problems have been recognised in various prior art documents.

In EP2830147-A an aluminium-air cell is provided in which a flow of electrolyte is provided to allow for removal of the gel sediment from the electrolyte.

In US4925744-B and US5049457-B a battery pack is provided by an assembly of individual cells, each individual cell being replaced once the aluminium electrode has been substantially consumed. The individual cells also allow for escape of hydrogen via a hydrophobic and gas permeable material. The patents recognised that forced air circulation

may be desirable to cool the individual cells, particularly when the ambient air temperature is elevated.

US3563803-B recognises the problem of corrosion of the aluminium electrode and proposes the addition of metal plumbites, plumbates or stannates to the electrolyte to relieve this problem.

US patent application 2004/0004431-A recognises the problem of corrosion of the aluminium electrode and proposes a solution to this problem by the inclusion in the cell of an anion-exchange membrane to separate the electrolyte solution on the side of the positive electrode from the electrolyte solution on the side of the negative electrode and allow the adjustment of the concentration of hydroxide ions of the aqueous solution on the side of the negative electrode to suppress the corrosion of the aluminium alloy. The cell also provides for circulation of the electrolyte solution between the inside and the outside of the cell so that it is possible to remove the aluminium hydroxide gel from the electrolyte solution outside of the cell.

WO01/33659-A describes in detail the function of an aluminium-air cell and deals with the issue of corrosion of the aluminium electrode by either providing for replaceable aluminium electrodes or by providing the electrolyte solution in a bag which can be punctured to commence operation of the cell (i.e. keeping the electrolyte separate from the aluminium electrode until needed). This is a system that is effective only once, since once the bag is punctured it cannot be resealed.

The present invention provides an aluminium-air cell as claimed in claim 1 or claim 26 or claim 27 and an aluminium air battery comprising a plurality of such cells. The present invention also provides a motor unit as claimed in claim 14 or claim 17 comprising the aluminium-air battery of the invention along with an electric motor. Preferred features of the aluminium-air cell are set out in claims 2 to 13 and 28 and 29 and preferred features of the motor unit are set out in claims 15 and 18 to 22.

The motor unit of the present invention is advantageously used in vehicles, including aircraft, for instance in drone aircraft, with the electric motor used to power a propeller of the drone aircraft. This will be further described later.

Preferred embodiments of the present invention will now be described in reference to the accompanying drawings in which:

Figure 1 is a cross section through a first aluminium-air cell and a half of a second aluminium-air cell, each cell being according to the present invention;

Figure 2 is a first perspective view of the aluminium-air cells of Figure 1;

Figure 3 is a second perspective view of the aluminium-air cells of Figure 1;

Figure 4 is a schematic illustration of an assembly of the aluminium-air cells of Figures 1 to 3 in a stack to form an aluminium-air battery which is connected to an electric motor to form a motor unit according to the present invention; and

Figure 5 is a schematic illustration of a modified version of the motor unit of Figure 4.

Throughout the specification where identical components are referred to in different cells, this is indicated by the component in the first cell being given a two digit number such as 13 and the identical component in the second cell being given a three digit number the last two digits of which are the same as the two digit number, such as 113.

In Figure 1 there can be seen the whole of one aluminium-air cell 10 according to the present invention and a half of an identical aluminium air cell 11 connected to the cell 10. The cell 11 is shown as illustrated to aid explanation, but it should be understood that the cell 11 will be identical to the cell 10. Only half of the aluminium-air celM 1 is shown for purposes of convenient illustration of the invention.

The aluminium-air cell 10 comprises a casing 12 comprised of two end caps 13 and 14 joined together. In figure 2 it can be seen that the end cap 113 is provided with an inwardly facing screw thread 160 which is threadably engageable with an outwardly facing screw thread on the other end cap (not shown). The provision of the mating threads on end caps such as 13 and 12 means that the end caps can easily be connected together and then disconnected by relative rotation, which enables easy replacement of the aluminium electrode, as will be described later. Within the casing there are a number of components assembled around a common shaft 15, which is rotatable within the casing 12. The casing 12 has apertures provided in the end caps 13 and 14 which align with the rotatable shaft 15. The apertures allow the connection of the rotatable shaft 15 to an external shaft (not shown in Figures 1-3, but described later in relation to Figure 4 and 5), which is a drive shaft for a battery comprising a plurality of the cells, as will be described later. The rotatable shaft 15 is tubular and has a central passage passing therethrough and open at both ends of the shaft, for instance the central passage in the shaft 115 of cell 11 opens at an end aperture 118, which can be seen in Figure 2. It can be seen from Figure 1 that the passages of the shafts 15 and 115 of aluminium-air cells 10 and 11 are aligned in use so that a common external shaft can pass through both passages, as will be described later with reference to Figure 4 and Figure 5.

Mounted on the rotatable shaft 15 for rotation therewith is a fan 20. This is most clearly seen in Figure 2, where fan blades such as 21 and 22 are shown.

Also mounted on the shaft 15 is an air cathode 23 formed as a circular plate. This comprises a frame formed of a circular perimeter support 24 and spokes such as 49, the frame supporting a multi-layer composite 25 of catalysed carbon particles in a mixture with a hydrophobic polymeric binder containing a fluro-carbon polymer. Either or both of the flat surfaces of the sheet 25 has pressed into it a foraminous metal mesh which can conduct current. The sheet 25 has an open porous construction which allows the flow of air, but which is impermeable to the flow of electrolyte through the sheet The air cathode 23 is mounted on the rotatable shaft 15 to rotate with the shaft 15, and four spokes are provided on one side of the air cathode (one of which can be seen as 49 in figure 3) and the rotation of the cathode 23 encourages electrolyte to flow to the periphery of the cell and to clear the reactive surface. Furthermore, relative rotation between the air cathode and the aluminium electrode also increases efficiency of the cell.

Facing the air cathode 23 and separated therefrom by a selected distance is an electrode 27 of aluminium or an alloy of aluminium. The electrode 27 is spaced from the air cathode 23 to form therebetween an electrolyte chamber, as will be described later. The electrode 27 is formed as a circular plate. The electrode 27 is fixed to the casing and remains stationary in use, i.e. stationary in the sense that it does not rotate with the shaft 15.

In Figures 1 to 3 there can also be seen a manifold 28, again mounted around the shaft 15, but which remains stationary in use. The manifold 28 has arms such as 29 and 30 (seen in all the Figures 1, 2, and 3) and 31, 32 (seen only in Figure 1) which provide air passages which align with apertures provided in the casing 12 (shown as 70, 71, 72 and 73 in figure 4) and allow air to flow from outside the casing 12 along the passages to a side of the air cathode 23 which faces the fan 20. The rotation of the fan 20 draws air in through the manifold 28 arms and directs the air to the surface of the air cathode 23. The air cathode 23 allows the air to pass through it into an electrolyte chamber 45 defined between the air cathode 23 and the facing electrode 27 of aluminium or aluminium alloy. The arms of the manifold can comprise annular passages defined by sleeves surrounding the manifold arms in order to provide flow paths for air to flow out of the cell to the exterior of the cell. These annular passages will also align with apertures in the casing of the cell, such as 70, 71, 72 and 73.

Not shown in the figures for reasons of clarity and ease of understanding, but also present in the casing 12, there is an absorbent foam mass, which will fill a reservoir cavity defined between the manifold 28 and the surrounding casing 12. For instance, the cavity parts 34A, 34B, 34C, and 34D, will all be filled by the absorbent foam mass. Preferably the

foam mass is of a graded absorbency, so as to naturally encourage flow of liquid absorbed by the material towards the rotatable shaft 15. The absorbent foam mass acts as a reservoir of electrolyte fluid, for instance a solution of potassium hydroxide. The absorbent foam mass will be made from a material which is inert and does not react with the electrolyte solution.

The rotatable shaft 15 is provided with an external Archimedes helical screw 35, provided in a chamber 36 defined by a part of the plastic moulding which forms the manifold 28. This plastic moulding will be provided with apertures which allow electrolyte fluid to be drawn from the absorbent foam mass into the chamber 36. The helical screw on rotation of the rotatable shaft 15 acts as an impeller and pumps electrolyte fluid out of the chamber 36 through delivery conduits such as 46 provided in a conduit section 37 of the rotatable shaft 19, the delivery conduits allowing flow of electrolyte fluid from the chamber 36 to the electrolyte chamber 45 defined between the air cathode 23 and the facing electrode 27 of aluminium or aluminium alloy.

Additionally or alternatively, the rotatable shaft 15 could be provided with a cam which compresses the absorbent foam mass on rotation in order to force electrolyte fluid out of the foam mass. Furthermore, rather than being provided within a separate chamber 36, the helical screw 35 could simply be surrounded by the absorbent foam mass and act directly onto the foam mass.

The moulding which provides the manifold 28 has a circular outer periphery wall 38 which extends over external peripheries of the fan 20 and of the air cathode 23. The periphery wall 38 defines between it and surrounding casing 12 an annular conduit which provides a return conduit to allow flow of electrolyte fluid from out of the electrolyte chamber 45 defined between the air cathode 23 and the electrode 27 of aluminium or aluminium alloy, back to the absorbent foam mass, via an absorbent wick provided in an annular passage of 0.6mm depth defined between the external surface of the circular perimeter support and the inwardly facing surface of the casing. The wick is annular in form and of a thin absorbent material

The electrically conducting metal mesh embedded in the air cathode 23 will be connected by wires passing through the rotatable shaft 15 to a copper slip ring (not shown in detail in the figures), which abuts with an inner race of a bearing 39 and then via an electrically conductive lubricant to an outer race of the bearing 39 which is connected to an engagement plate 180 which will engage the electrode 27 of aluminium or aluminium alloy of the neighbouring aluminium-air cell, as can be seen in Figure 1, or which abuts with a terminal providing an output from a stack of cells which together form an aluminium- air

battery. The engagement plate 80 could be mounted in the casing to be slidable axially along the shaft 19 and biased by springs to be pushed into engagement with the aluminium electrode 27. The spring-biased plate 80 could push and keep the electrode 27 up against spokes 49 which keep the face of the electrode 27 facing the cathode 23 spaced from the opposing cathode face by a chosen distance, e.g. 0.6 mm. Leaf springs can be used to bias the engagement plate. The leaf springs can provide a conductive path from the outer race of the bearing to the electrode.

Figure 4 shows a motor unit 50 comprising an assembly of aluminium-air cells in a stack to form an aluminium-air battery, each cell being as described above. The first aluminium-air cell 10 is shown, along with the second aluminium air cell 11 and then three other identical aluminium-air cells 40, 41, and 42 are shown. The motor unit 50 also comprises an electric motor 51 which drives an output shaft 52. The shaft 52 extends through all of the cells 10, 11, 40, 41 and 42, the output shaft 52 extending through passages in the tubular rotatable shafts of each of the cells, so that the rotatable shaft of each of the cells rotates with rotation of the output shaft 52. The battery formed by the stack of cells is connected by wires 53 and 54 to an electronic controller 55, which is then connected to a small starter battery 55, which is a conventional rechargeable battery, e.g. a lead-acid battery or a nickel-cadmium battery or a lithium-ion battery.

The electronic controller 55 controls transmission of power from the stack of cells 10, 11, 40, 41, and 42 to the electric motor 51. The electronic controller 55 also controls connection of the small starter battery 56 to the electric motor 51 and also connection of the starter battery 56 to the aluminium-air battery.

The output shaft 52 shown in Figure 4 in use is connected to drive whatever is needed, e.g. the motor unit 50 could be included in an electrically powered drone aircraft and the output shaft 52 connected to a propeller of the aircraft to rotate the propeller.

Figure 5 shows a modification of the Figure 4 motor unit. The modified unit 60 is largely identical to the motor unit 50 and identical elements are given identical reference numerals in the Figures. For the sake of brevity, only differences between the motor units 50 and 60 will be described. The motor unit 60 has an output shaft 61 which provides drive outside of the motor unit (e.g. to a propeller as described above). The electric motor 51 also has a second output shaft 62 which is connected to a gearbox 63. A drive shaft 64 extends from the gearbox 63 through the rotatable shafts of the aluminium-air cells 10, 11, 40, 41, and 42, to rotate these shafts. The gearbox 63 allows the rotatable shafts of the aluminium-air cells to be rotated at a speed different to the speed of the output shaft 61.

Operation of the motor units 50 and 60 and of the aluminium-air batteries thereof, and of the cells in the batteries, including the aluminium air cell 10 described in Figures 1-3, will now be described.

To start the motor unit 50 or 60, the control unit 55 connects the starter battery 56 to the electric motor 51, which then turns the output shaft 52 or 62. Initially, in each aluminium-air cell the electrolyte solution will be stored wholly or at least in the majority within the absorbent foam mass in the cell. As the output shaft 52 or 62 of the motor is rotated then the rotatable shaft within each cell, e.g. the shaft 15 within the cell 10, is driven to rotate. This rotation causes the helical screw 35 of each cell to rotate and to pump liquid electrolyte into the electrolyte chamber defined between the air cathode 23 and the facing electrode 27 of aluminium or aluminium alloy. At the same time, the rotating shaft causes the fan 20 of each cell to rotate and to draw in air via the manifold 28 and to direct this air on to the face of the air cathode 23 which faces away from the electrode 27 of aluminium or aluminium alloy. The air cathode 23 allows oxygen cations to pass through it to the electrolyte chamber between the air cathode 23 and the electrode 27. This electrolyte chamber is filled with liquid electrolyte, pumped into the chamber by the rotating helical screw 35. At this point each of the cells 10, 11, 40, 41 and 42 begins to function and to generate electrical power and the electrical power generated by the stack of cells 10, 11, 40, 41, and 42 is delivered via the wires 54 to the control unit 55, which then passes the electrical power to the motor 51 to drive the motor. When the stack of cells in the aluminium-air battery generates sufficient power then the controller 55 will disconnect the starter battery 56 from the motor 51. The motor 51 then continues to be driven by the power generated by the stack of cells 10, 11, 40, 41, and 42 of the battery. During this period some electrical power generated by the stack of cells 10, 11, 40, 41, and 42 of the battery can be used to recharge the starter battery 56, under the control of the electronic controller 55.

During operation of the cells in the battery there will be a flow of electrolyte in each cell. The electrolyte liquid is drawn from the foam mass and pumped into the centre of the cylindrical electrolyte chamber 45 formed between the cathode 23 and the electrode 27. The electrolyte flows radially outwardly from the centre across the opposed faces of the air cathode 23 and the electrode 27 of aluminium or aluminium alloy, eventually reaching the annular passage defined between the peripheral wall 38 and the adjacent casing and passing through the return conduit provided by this annular passage back to the foam mass.

During operation, the foam mass will act to filter from the electrolyte any contaminants in the electrolyte, e.g. any hydroxide gel formed during the battery operation.

During operation, the aluminium or aluminium alloy electrode 27 will be gradually consumed, but a good electrical contact is maintained between the electrode 27 and the slip ring of an adjacent cell or a slip ring connected to an output terminal of the battery comprising the stack of cells.

The cells of the stack can be replaced once the aluminium or aluminium alloy electrodes have been consumed. Each cell can be replaced individually as to the performance of the battery deteriorates.

In order to stop the motor unit 50 or 60, the electronic controller 55 stops the power supply to the motor 51 and therefore the output shafts 52,62 are brought to a standstill. This means that the rotating shafts within the cells 10, 11, 40, 41 and 42 are also brought to a standstill and this means that the helical screws on the exterior of the shafts cease to rotate and therefore cease to pump electrolyte fluid. The electrolyte fluid in the cylindrical electrolyte chamber between the air cathode 23 and the electrode 27 is wicked into the absorbent foam mass to substantially clear the electrolyte chamber of electrolyte fluid. This is important to prevent unnecessary corrosion of the electrode 27 of aluminium or aluminium alloy while the battery is not operational.

From the above it will be understood that the battery is provided with stop and start functionality by controlling the presence of the electrolyte in the electrolyte chamber 45. This is an important feature of the battery, which improves operation and life.

While the flow of air to and into the air cathode 23 is an intrinsic part of the operation of each aluminium-air cell the flow of air also serves as a cooling purpose and ensures that the components of the cell remain sufficiently cool. The air can leave the casing through annular passages formed as outer sleeves surrounding one or more of the arms of the manifold, as described earlier.In each cell there will be hydrogen generated during operation. A reed valve vent can be provided in the casing to allow escape of the hydrogen from the cell to prevent a build-up of hydrogen within the cell.

In each cell as described above, it is preferred that the gap between the facing surfaces of the cathode and anode is 0.5mm. The parts of the casing and the fan and the manifold are preferably injection moulded parts formed of thermoplastic or thermoset materials. The slip ring is preferably a copper slip ring and preferably titanium grids are included and embedded in both the cathode and the electrode of aluminium or aluminium alloy as conductors of electricity.

The output of each aluminium-air cell will have a functional relationship to the speed of rotation of the rotatable shaft of the cell, since the speed of rotation of the rotational hub will affect the flow of electrolyte through the electrolyte chamber and also will affect the amount of air driven by the fan onto the air cathode.

It is envisaged that the gearbox 63 shown in Figure 5 might be a gearbox that allows a variable transmission ratio, controllable by the controller unit 55 and the controller unit 55 could control the ratio selected in order to control the output of the battery comprising the stack of cells 10, 11, 40, 41 and 42.

A series of seals such as '0' rings will be provided where needed to seal the casing and prevented unwanted escape of electrolyte from the casing.

Whilst in Figures 5 and 6 a stack of five cells are used to provide a battery, this is purely illustrative and any number of cells could be included in a stack. Typically a clamp will be provided to clamp the cells together in the stack. The clamp will be releasable to allow replacement of one or more of the cells in the stack. To permit this, the shaft 64 shown in Figure 5 could be releasably coupled to the gearbox 63 and withdrawn from the cells of the stack to allow replacement of one or more of the cells.

The motor units of figures 4 and 5 can be used as motor units in vehicles, including land vehicles, marine vehicles (boats and amphibious craft) and also aircraft, including drone aircraft. The aluminium-air cells and batteries could also be static e.g. to supply electricity in a domestic situation.

As mentioned above each cell comprises a casing which is formed in two parts, which are provided with matching screwthreads so that the parts can be simply and quickly coupled and uncoupled. This allows for rapid refuelling of the cell. The casing components are uncoupled and then a spent aluminium electrode removed and replaced. Ideally the aluminium electrode will be snap-fitted in place (either the electrode could have resilience itself allowing a snap-fitting and/or resilient detents provided in casing to releasably retain the electrode in place). Furthermore, the foam components which act as reservoirs for the electrolyte can be designed to be easily removable and replaceable to allow reconditioning of the cell. Once the foam components are removed then any residual electrolyte can be easily washed out of the casing. The new foam components can pre-loaded with electrolyte so that the electrolyte in the cell can be replenished just be replacing the foam components.

CLAIMS:

1. An aluminium-air cell comprising:

a casing and within the casing:

an air cathode;

an electrode of aluminium or aluminium alloy spaced from the air cathode;

an electrolyte chamber defined between the air cathode and the electrode;

an electrolyte liquid;

a reservoir cavity separate from the electrolyte chamber for storing the electrolyte liquid;

a rotatable shaft;

a delivery conduit connecting the reservoir cavity and the electrolyte chamber; and

an impeller device driven by the rotatable shaft to draw the electrolyte liquid out of the reservoir and pump the drawn electrolyte liquid through the delivery conduit into the electrolyte chamber.

2. An aluminium-air cell as claimed in claim 1 wherein the impeller is a screw pump provided on the exterior of a part of the rotatable shaft.

3. An aluminium-air cell as claimed in claim 1 and 2 wherein:

the air cathode is mounted on the rotatable shaft with the rotatable shaft extending therethrough; and

the delivery conduit is formed in the rotatable shaft; whereby

the electrolyte liquid can be drawn from the reservoir located on a first side of the air cathode and delivered to the electrolyte chamber on a second side of the air cathode opposite to the first side.

4. An aluminium-air cell as claimed in any of claims 1 - 3 wherein a fan is mounted on the rotatable shaft for rotation therewith and the fan on rotation generates a current of air directed toward the air cathode.

5. An aluminium-air cell as claimed in claim 4 comprising a manifold within the casing which has at least one arm which provides a channel through which air can be drawn by the fan, the channel extending to or through an aperture in the casing to allow air to be drawn from outside the casing.

6. An aluminium-air cell as claimed in claim 5 where the manifold has a plurality of arms each providing a channel through which air can be drawn by the fan, the channel of each arm extending to or through an aperture in the casing individual to the arm.

7. An aluminium-air cell as claimed in any of the preceding claims comprising a foam mass located in the reservoir cavity which can absorb and store the electrolyte liquid.

8. An aluminium-air cell as claimed in claim 7 where a cam is provided on the rotatable shaft which when rotated compresses the foam mass to squeeze electrolyte liquid out of the foam mass.

9. An aluminium-air cell as claimed in any one of the preceding claims comprising a return conduit, independent from the delivery conduit, which connects the electrolyte chamber with the reservoir cavity to allow electrolyte fluid to be returned from the electrolyte cavity to the reservoir cavity.

10. An aluminium-air cell as claimed in claim 9 wherein a wick is provided in the return conduit which wicks electrolyte out of the electrolyte chamber.

11. An aluminium-air cell as claimed in any one of the preceding claims wherein the air cathode is formed as a plate and comprises an array of metallic conductive elements via which current is conducted to an electrical conductor extending along the rotatable shaft to a terminal exposed to the exterior of the casing.

12. An aluminium-air cell as claimed in any one of the preceding claims wherein the electrode of aluminium or aluminium alloy is formed as a plate and is mounted on the rotatable shaft with the rotatable shaft extending through the electrode, the electrode comprising or being connected to a terminal exposed to the exterior of the casing.

13. An aluminium-air cell as claimed in any one of the preceding claims wherein the rotatable shaft is tubular and extends through the casing from a first shaft aperture

on a first side of the casing to a second shaft aperture on a second side of the casing and the tubular rotatable shaft has a passage formed therein which extends along the entire length of the rotatable shaft and opens on to both ends of the shaft.

14. A motor unit comprising:
an aluminium-air cell as claimed in any one of claims 1 to 13;
an electric motor with an output shaft;
a starter battery; and
an electronic controller electrically connected to the aluminium-air cell, the electric motor and the starter battery; wherein:
the output shaft engages or is coupled with the rotatable shaft of the aluminium- air cell so that the rotatable shaft rotates with rotation of the output shaft;
on starting of the motor unit the electronic controller connects the starter battery to the electric motor to supply power to the electric motor, whereby the electric motor starts to rotate;
the rotation of the electric motor is relayed via the output shaft and the rotatable shaft to the impeller which is driven to draw the electrolyte liquid from the reservoir and pump the liquid via the delivery conduit to the electrolyte chamber;
introduction of the electrolyte liquid within the electrolyte chamber initiates operation of the aluminium-air cell and electrical power generated by the aluminium-air cell is relayed to the electric motor to drive the electric motor; and
once sufficient power is generated by the aluminium-air cell, then the electronic controller disconnects the starter battery from the electric motor.

15. A motor unit as claimed in claim 14 wherein the electronic controller can stop operation of the motor unit and stop power production by the aluminium-air cell by disconnecting the electric motor from the aluminium-air cell and the starter battery so that the motor and hence the shaft stop rotating and supply of electrolyte liquid to the electrolyte chamber is suspended.

16. An aluminium-air battery comprising a stack of aluminium-air cells each as claimed in any one of claims 1 to 13.

17. A motor unit comprising:
an aluminium-air battery as claimed in claims 16;

an electric motor with an output shaft;

a starter battery; and

an electronic controller electrically connected to the starter battery, the electric motor and the aluminium-air battery; wherein:

the output shaft engages or is coupled with the rotatable shafts of all of the cells in the aluminium-air battery so that the rotatable shafts all said cells rotate with rotation of the output shaft;

on starting of the motor unit the electronic controller connects the starter battery to the electric motor to supply power to the electric motor, whereby the electric motor starts to rotate;

rotation of the electric motor is relayed via the output shaft and the rotatable shafts of all of the cells of the aluminium-air battery to the impellers of the cells which are driven to draw the electrolyte liquid from the reservoirs of the cells and pump the liquid into the electrolyte chambers of the cells;

introduction of the electrolyte liquid into the electrolyte chambers initiates operation of the cells of the aluminium-air battery and the electrical power generated by the aluminium-air battery is relayed to the electric motor to drive the electric motor; and

once sufficient electrical power is generated by the aluminium-air battery then the electrical controller disconnects the starter battery from the electric motor.

18. A motor unit as claimed in claim 17 wherein the electronic controller can stop operation of the motor unit and stop power production by the aluminium-air battery cell by disconnecting the electric motor from the aluminium-air battery and the starter battery so that the motor and hence the shaft stop rotating and supply of electrolyte liquid to the electrolyte chambers of the cells of the aluminium-air battery is suspended.

19. A motor unit as claimed in claim 17 or claim 18 when dependent on claim 13 wherein the output shaft extends through the rotatable shafts of all of the cells of the aluminium-air battery or the output shaft is coupled via a gearbox to a driveshaft which extends through the rotatable shafts of all of the cells of the aluminium-air battery.

20. A motor unit as claimed in any one of claims 17 to 19 where each cell in the aluminium-air battery is individually replaceable.

21. A motor unit is claimed in any one of claims 17 or claim 20 wherein the output shaft and the rotatable shaft are coupled via a gearbox.

22. A motor unit as claimed in any one of claims 17 to 21 where the starter battery is rechargeable and electric power output from the aluminium-air battery is used to recharge the starter battery.

23. A vehicle comprising a motor unit as claimed in any of one claims 17 to 22.

24. An aircraft comprising a motor unit as claimed in any one of claims 17 to 23.

25. An aircraft as claimed in claim 24 which is a drone aircraft.

26. An aluminium-air cell comprising:
a casing and within the casing;
an air cathode;
an electrode of aluminium or aluminium alloy spaced from the air cathode;
an electrolyte chamber defined between the air cathode and the electrode;
an electrolyte liquid;
a foam mass located in a reservoir cavity separate from the electrolyte chamber which can absorb and store the electrolyte liquid;
a delivery conduit connecting the reservoir cavity to the electrolyte chamber; and
an impeller for drawing the electrolyte liquid out of the foam mass and pumping the drawn electrolyte liquid through the delivery conduit into the electrolyte chamber.

27. An aluminium-air cell comprising:
a casing and within the casing;
an air cathode;
an electrode of aluminium or aluminium alloy spaced from the air cathode;
an electrolyte chamber defined between the air cathode and the electrode;
an electrolyte liquid;
a reservoir cavity separate from the electrolyte chamber which can store the electrolyte liquid;
a delivery conduit connecting the reservoir cavity to the electrolyte chamber; and
an impeller for drawing the electrolyte liquid out of the foam mass and pumping the drawn electrolyte liquid through the delivery conduit into the electrolyte chamber;
wherein:

the casing comprises at least two casing parts releasably connected together and the electrode of aluminium or aluminium alloy is mounted with a first casing part so that the electrode when degraded can be replaced by disconnecting the first casing part from the remaining casing part(s), removing the degraded electrode from the first casing part, securing a new electrode in the first casing part and then reconnecting the first casing part to the remaining casing part(s); and

the electrode of aluminium or aluminium alloy is snap-fitted in place in the first casing part by: using a resilient electrode which can be flexed to allow snap-fitting with detents provided in the first casing part; and/or by providing resilient detents in the first casing part to releasably retain the electrode within the first casing part.

28. An aluminium-air cell as claiming in claim 27 wherein foam components are provided in the reservoir cavity which act as reservoirs for the electrolyte and the foam components are removable from the reservoir cavity and replaceable to allow reconditioning of the cell.

29. A method of reconditioning the aluminium-air cell of claim 28 comprising removing the foam components from the cell and replacing them with new foam components pre-loaded with fresh electrolyte liquid.

30. An aluminium-air cell substantially as hereinbefore described with reference to and as shown in figures 1, 2 and 3.

31. A motor unit substantially as hereinbefore described with reference to and as shown in the accompanying figures 4 and 5.

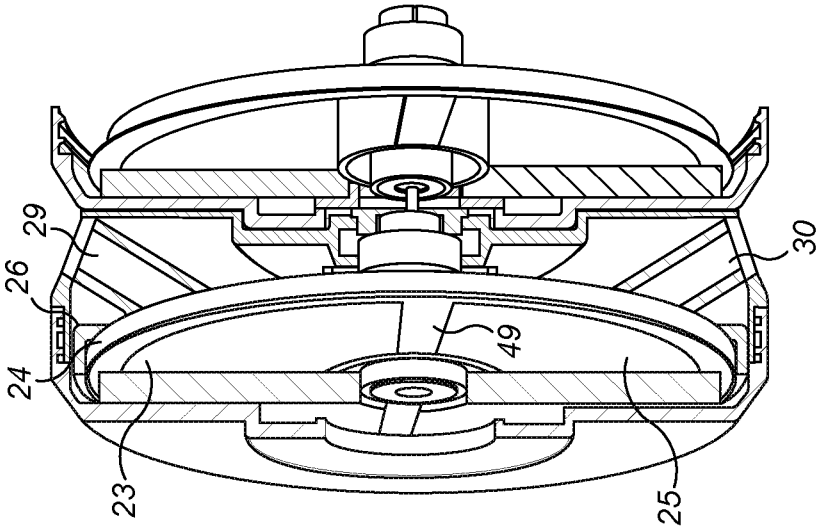

FIG. 3

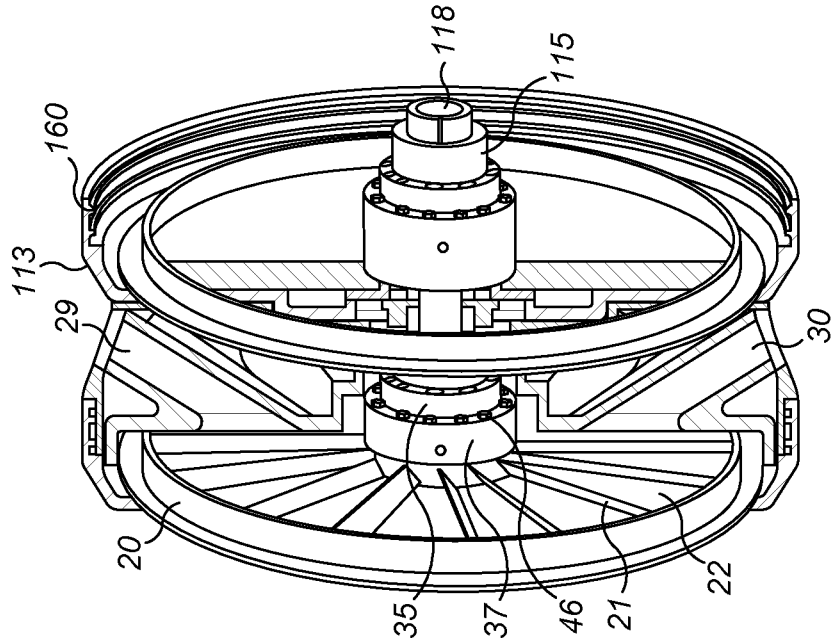

FIG. 2

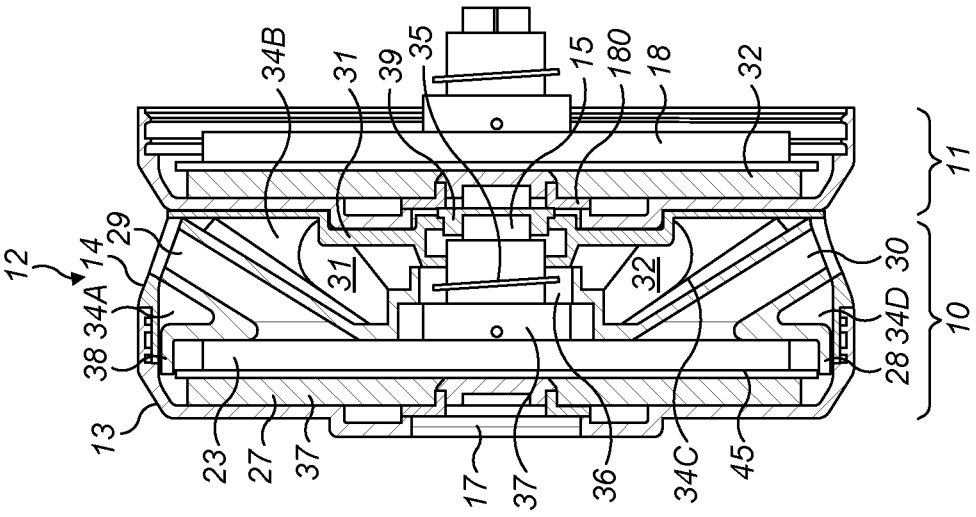

FIG. 1

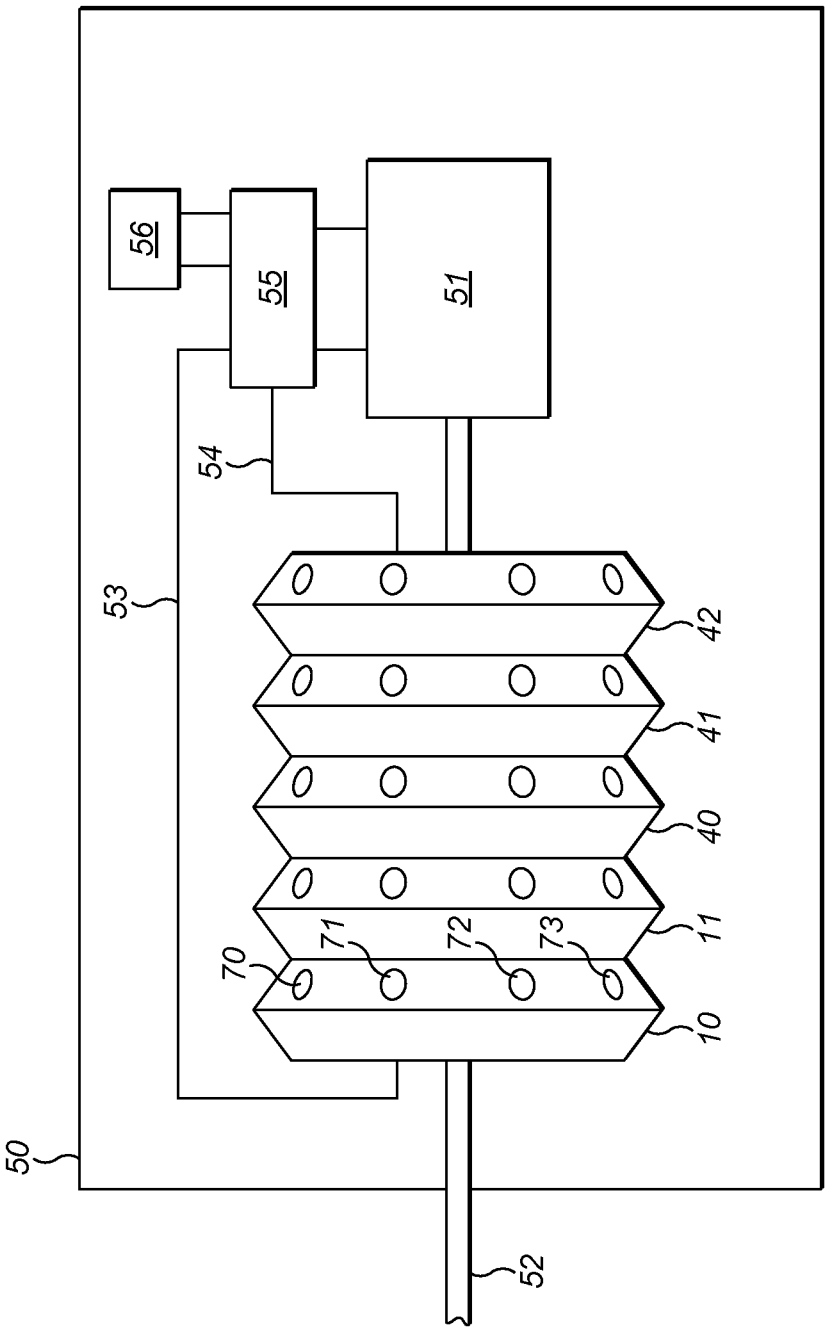

FIG. 4

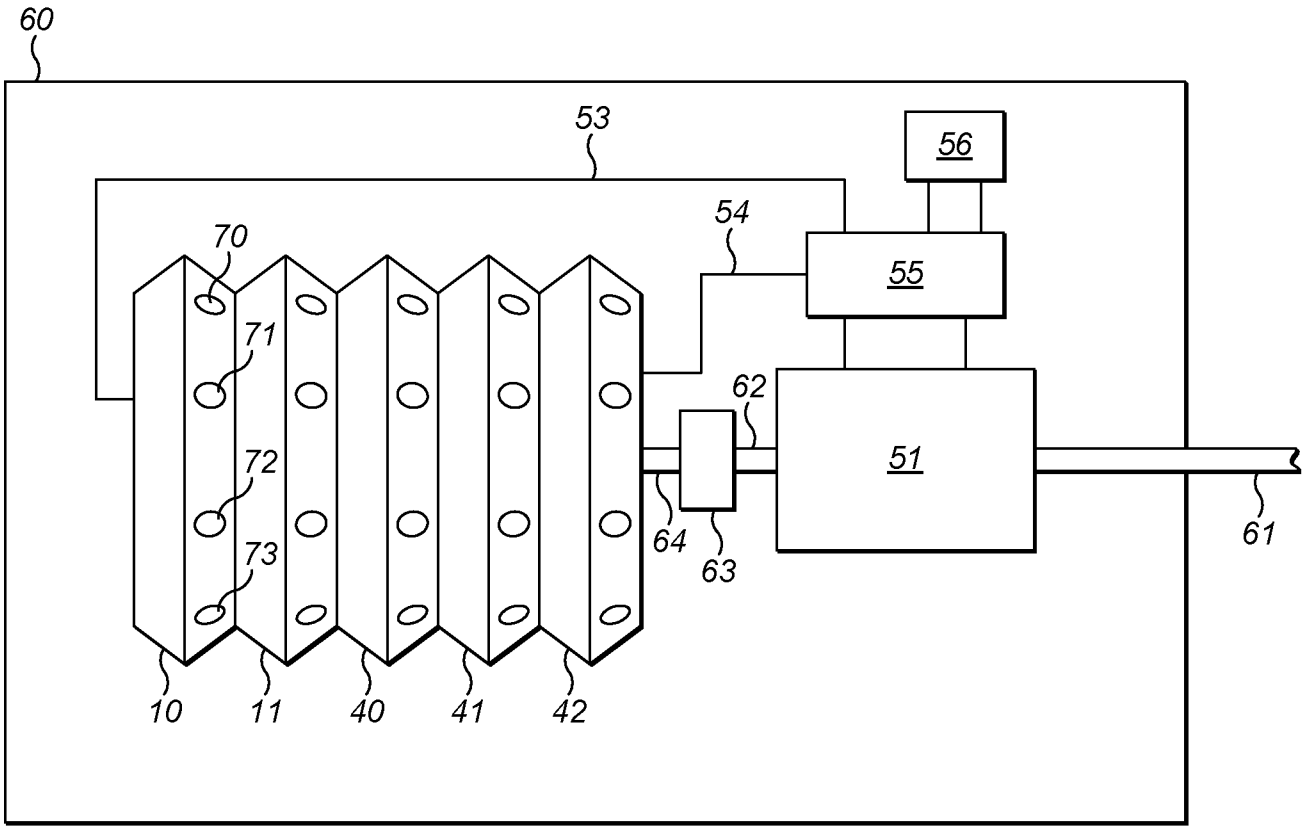

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/051274

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M2/38 H01M10/42 H01M12/06 B60L11/18 B64C39/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M B60L B64C

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 977 729 A (CELESTE SALVATORE ALBERT [US]) 2 November 1999 (1999-11-02)	1,4-6,9 , 16
Y	column 3 - column 6; figures 2, 3, 5, 9	2,7,10, 26
A		8

X	EP 0 911 896 Al (EUROP ECONOMIC COMMUNITY [LU]) 28 April 1999 (1999-04-28) paragraphs [0040] - [0048]; figures 1, 2	1,3, 11-13

Y	US 2013/309581 Al (YAMAGUCHI TAKITAR0 [JP] ET AL) 21 November 2013 (2013-11-21) paragraph [0078]	2

Y	EP 1 859 505 Al (EVEREADY BATTERY INC [US]) 28 November 2007 (2007-11-28)	7,26
A	paragraphs [0033] - [0038]	8

	-/- ·	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

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

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

"L" documentwhich may throw doubts on priority claim(s) orwhich 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 to 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 when the document is taken alone

"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

Date of the actual completion of the international search	Date of mailing of the international search report
15 September 2016	23/09/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hofer, Astrid

7

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 637 852 A1 (SAFT AMERICA INC [US]) 8 February 1995 (1995-02-08) column 5 -----	10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2016/051274

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

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

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

2. ☒ Claims Nos.: 30, 31
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:

see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

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

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos. :

1-13 , 16, 26

4. ☐ 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 claims Nos. :

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 2-6, 11-13, 16(completely) ; 1, 9(partially)

   An aluminium-air cell according to claim 1 whereby the impeller is a screw pump.

   ---

2. claims: 7, 8, 10, 26(completely) ; 1, 9(partially)

   An aluminium-air cell according to claim 26, whereby a foam mass located in a reservoir cavity.

   ---

3. claims: 14, 15, 17-25 (completely) ; 1 (partially)

   A motor unit comprising: an aluminium-air cell as claimed in claim 1; an electric motor with an output shaft; a starter battery; and an electronic controller electrically connected to the aluminium-air cell, the electric motor and the starter battery.

   ---

4. claims: 27-29

   An aluminium-air cell comprising a casing wherein the casing comprises at least two casing parts releasably connected together.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 30, 31

Claims 30 and 31 contain references to the the drawings. According to Rule 6.2 (a) PCT, claims should not contain such references except where absolutely necessary, which is not the case here.

The terms "hereinbefore" and "substantially" used in claims 30 and 31 are vague and unclear and leave the reader in doubt as to the meaning of the technical feature to which they refer, thereby rendering the definition of the subject-matter of said claims unclear, Article 6 PCT. Furthermore it is not clear if "hereinbefore" refers to any of the claims or to the description.

The claims contain no further technical features.

The non-compliance with the substantive provisions is to such an extent that no meaningful search of claims 30, 31 could be carried out at all (Article 17(2) PCT).

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EP0 policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EP0, the applicant is reminded that a search may be carried out during examination before the EP0 (see EP0 Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2016/051274

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