SPLIT SERPENTINE FLOW FIELD PLATE, SYSTEM AND METHOD

TECHNICAL FIELD

[0001]The present disclosure relates generally to an accumulator system and more particularly to a split serpentine flow field plate, system, and method.

BACKGROUND

[0002] A reduction-oxidation flow battery or flow battery is a type of electrochemical cell where chemical energy is provided by two chemical components dissolved in liquids that are pumped through the system on separate sides of a membrane. The charge-discharge duty of the flow battery requires the circulation of electrolytes from external reservoirs through the cells. The flow battery includes a positive and negative porous electrode that are separated by a membrane.

[0003] The performance of the charge-discharge life cycle of a flow battery depends on the mechanism of circulation of electrolytes through the electrodes. The effective circulation to meet the desired electrochemical performance of a flow battery is attributed to the uniform distribution of reactant species across the electrode and quick evacuation of product species from the electrode region at low fluid traverse resistance. An uneven supply of electrolytes in the electrodes results in loss of performance. Significant attenuation of performance may be caused at high current densities due to insufficient replenishment or removal of species.

[0004] Flow field plate plays a vital role in the performance of the flow batteries as it distributes the electrolyte in the flow batteries. These flow field plates are made of a suitable electrically conducting material and serve as current collectors to provide electrical continuity between the cell voltage terminals and electrodes.

[0005] The serpentine flow field is one among several flow field variants that has been investigated significantly for application in electrochemical cells.

[0006] Serpentine flow channels traverse continuously from inlet to outlet with several hairpin turns and switchbacks by covering the entire area of the electrode thus providing electrolyte species across all the active sites of the electrode.

[0007] The limitations associated with the currently available serpentine flow are that a long flow path with several turns typically involves a large unfavourable pressure drop between the inlet and outlet which translates to significant parasitic power consumption, poor replenishment removal of reactant and product species, respectively, and long flow channels results in high reactant gradient from inlet to outlet leading to over-potential losses and ineffective utilization of active sites of electrode thus reducing the efficiency of a charge-discharge life cycle.

[0008] Another available flow field plate with a serpentine configuration includes an openfaced fluid flow channel that includes a plurality of passes. Such transversal of the entire area of the electrode eliminates stagnant regions and thus provides uniform distribution. The long reactant flow path generates a large pressure drop and flooding of electrolytes in the electrode. Another available flow field plate with multiple serpentines to overcome limitations representing the pressure drop has its own limitation that is decreased rate in the number of flow channels where the number of channels in the inlet side is greater than the number of downstream passages that cause exponential decay in number of flow channels.

[0009] Therefore, there is a need for a plate to overcome the limitations associated with serpentine type flow field with unfavourable pressure drop, ineffective utilization of active sites of electrodes thus reducing the efficiency of a charge-discharge life cycle, uneven distribution of electrolyte in the electrodes of a flow type battery.

SUMMARY

[0010] In one aspect of the present disclosure, a flow field plate may be provided. The flow field plate may include an inlet port to receive a first electrolyte, a first inlet, a second inlet, a third inlet, a fourth inlet for collecting the first electrolyte from the inlet port, and further adapted to deliver the collected electrolyte to a first quadrant, a second quadrant, a third quadrant, and a fourth quadrant respectively, a drain canal that is adapted to collect a reacted first electrolyte from each quadrant of the first quadrant, the second quadrant, the third quadrant, and

the fourth quadrant and further transfers the collected first electrolyte to an outlet port.

BRIEF DESCRIPTION OF DRAWINGS

[0011] The above and further features and advantages of aspects of the present disclosure become apparent upon consideration of the following detailed description of aspects thereof, especially when taken in conjunction with the accompanying drawings–to facilitate understanding, like reference numerals have been used, where possible, to designate like elements common to the figures–and wherein:

[0012] **FIG. 1** illustrates a set of plates of a battery pack system, in accordance with an aspect of the present disclosure;

[0013] **FIG. 2A** illustrates a front view of a flow field plate in the set of plates, in accordance with an aspect of the present disclosure;

[0014] **FIG. 2B** illustrate a front view of the flow field plate in the set of plates, in accordance with an aspect of the present disclosure;

[0015] **FIG. 2C** illustrates a magnified view of an inlet corner of the flow field plate, in accordance with an aspect of the present disclosure; and

[0016] **FIG. 2D** illustrates a magnified view of an outlet corner of the flow field plate, in accordance with an aspect of the present disclosure.

DETAILED DESCRIPTION

[0017] Various aspect of the present disclosure provides a split serpentine flow field plate, system, and method. The following description provides specific details of certain aspects of the disclosure illustrated in the drawings to provide a thorough understanding of those aspects. It should be recognized, however, that the present disclosure can be reflected in additional aspects and the disclosure may be practiced without some of the details in the following description.

[0018] The various aspects including the example aspects are now described more fully with reference to the accompanying drawings, in which the various aspects of the disclosure are shown. The disclosure may, however, be embodied in different forms and should not be construed as limited to the aspects set forth herein. Rather, these aspects are provided so that this disclosure is thorough and

complete, and fully conveys the scope of the disclosure to those skilled in the art. In the drawings, the sizes of components may be exaggerated for clarity.

[0019] It is understood that when an element or layer is referred to as being "on," "connected to," or "coupled to" another element or layer, it can be directly on, connected to, or coupled to the other element or layer or intervening elements or layers that may be present. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0020] The subject matter of example aspects, as disclosed herein, is described with specificity to meet statutory requirements. However, the description itself is not intended to limit the scope of this disclosure. Rather, the inventor/inventors have contemplated that the claimed subject matter might also be embodied in other ways, to include different features or combinations of features similar to the ones described in this document, in conjunction with other technologies.

[0021] Generally, the various aspects including the example aspects relate to a split serpentine flow field plate and system. As mentioned, there remains a need for a plate to overcome the limitations associated with serpentine-type flow field with unfavourable pressure drop, ineffective utilization of active sites of electrodes thus reducing the efficiency of a charge-discharge life cycle, uneven distribution of electrolyte on the electrodes of a flow type battery. The present disclosure, therefore, provides a split serpentine flow plate, system, and method that uniformly distributes the electrolyte across the electrodes.

[0022] **FIG. 1** illustrates a perspective view of a set of plates **100** of a battery pack system, in accordance with an aspect of the present disclosure. The set of plates **100** may be disposed inside a battery pack system. In some aspects of the present disclosure, the battery pack system may be provided with one or more sets of plates **100**. In some aspects of the present disclosure, each set of plates **100** may be adapted to pass anolyte and catholyte respectively.

[0023] The set of plates **100** may include a flow field plate**102**, a current collector **104**, a graphite felt electrode **106**, an insulated plate **108**, a flow frame **110**, a compressible gasket **112**, and a polymer membrane **114**.

[0024] The flow field plate **102** may include a plurality of channels, wherein each

channel may facilitate a first electrolyte to circulate on the plurality of channels provided on the flow field plate **102** thereby reacting with the current collector **104**. In some aspects of the present disclosure, the flow field plate **102** may be adapted to pass the first electrolytes across the channels provided on the flow field plate **102**.

[0025] The current collector **104** may be disposed adjacent to a first side **118** of the flow field plate**102**. In some aspects of the present disclosure, the current collector **104** enables a flow of electrons from the first electrolyte to an external electrode while discharging.

[0026] In some aspects of the present disclosure, the current collector **104** enables a flow of electrons from the external electrode to the first electrolyte electrode while charging. In some aspects of the present disclosure, the current collector **104** may be a copper current collector.

[0027] The graphite felt electrode **106** may be disposed adjacent to a second side **120** of the flow field plate**102**. The graphite felt electrode **106** may be adapted to prevent the flow of electrons to the second side **120** of the flow field plate**102**. Such that the electrons pass only through the current collector **104**.

[0028]The insulated plate **108** may be disposed adjacent to the current collector **104**. In some aspects of the present disclosure, the insulated plate **108** and the flow field plate**102** may sandwich the current collector **104**. In some other aspects of the present disclosure, insulated plate **108** may be a non-conducting material. In some aspects of the present disclosure, the insulated plate **108** may be adapted to provide mechanical strength to the set of plates **100**. In some aspects of the present disclosure, the insulated plate **108** may be adapted to provide mechanical support to the set of plates **100**. The set of plates **100** may further include an end plate **116**.

[0029]The end plate **116** may provide mechanical strength and structure to the set of plates **100**. In some aspects of the present disclosure, the end plate **116** may be adapted to prevent the set of plates **100** from deformation. In some aspects of the present disclosure, the insulated plate **108** and the end plate **116** may be replaced by a single plate with mechanical strength and non-conductive

properties.

[0030] The flow frame **110** may be disposed adjacent to the graphite felt electrode **106**. In some aspects of the present disclosure, the flow frame **110** and the flow field plate**102** may sandwich the graphite felt electrode **106**.

[0031] The flow frame **110** may be adapted to restrict the flow of a first electrolyte by providing a sealing effect. In some aspects of the present disclosure, the flow frame **110** may be adapted to bind the flow field plate**102** and the graphite felt electrode **106** together and further may enable the first electrolyte to flow across the flow field plate**102**.

[0032] In some aspects of the present disclosure, the flow frame **110** may be a non-porous and non-permeable frame. In some aspects of the present disclosure, the flow frame **110** may be a graphite frame with high electrical conductivity. In some aspects of the present disclosure, the electrical conductivity of the graphite frame may be **104** Siemens per centimetre (s/cm).

[0033] The compressible gasket **112** may be disposed adjacent to the flow frame **110**. In some aspects of the present disclosure, the compressible gasket **112** and the graphite felt electrode **106** may sandwich the flow frame **110**. In some aspects of the present disclosure, the compressible gasket **112** may be adapted to seal each cell of the set of plates **100**. In some aspects of the present disclosure, the compressible gasket **112** may be adapted to compress the graphite felt electrode **106** with the flow frame **110** to achieve optimum performance.

[0034] The polymer membrane **114** may be disposed adjacent to the compressible gasket **112**. The polymer membrane **114** may be adapted to prevent cross-mixing of the first electrolyte with a second electrolyte. In some aspects of the present disclosure, the polymer membrane **114** may be adapted to prevent a short circuit of set of plates **100** with a second set of plates of the battery pack system (not shown) during transfer of ions to complete a circuit.

[0035] **FIG. 2A** illustrates a front view of a flow field plate **102** in the set of plates, in accordance with an aspect of the present disclosure; **FIG. 2B** illustrates a front view of the flow field plate **102** in the set of plates, in accordance with an aspect of the present disclosure. **FIG. 2C** illustrates a magnified view of an inlet corner

"A" of the flow field plate **102**, in accordance with an aspect of the present disclosure.

[0036] **FIG. 2D** illustrates a magnified view of an outlet corner "B" of the flow field plate **102**, in accordance with an aspect of the present disclosure. The flow field plate **102** may include an inlet port **202**, a first inlet **204**, a second inlet **206**, a third inlet **208**, a fourth inlet **210**, a first quadrant **212**, a second quadrant **214**, a third quadrant **216**, and a fourth quadrant **218**, a drain canal **220**, an outlet port **222**. The inlet port **202** may facilitates flow of the first electrolyte through the inlet port **202**.

[0037] In some aspects of the present disclosure, the inlet port **202** may be coupled with an input tube of a first electrolyte tank. The inlet port **202** may further distribute the first electrolytes among the first inlet **204**, the second inlet **206**, the third inlet **208**, and the fourth inlet **210**.

[0038] The first inlet **204** may facilitate the flow of the first electrolyte from the inlet port **202** to the first quadrant **212**. The second inlet **206** may facilitate the flow of the first electrolyte from the inlet port **202** to the second quadrant **214**. The third inlet **208** may facilitate flow of first electrolyte from the inlet port **202** to the third quadrant **216**. The fourth inlet **210** may facilitate flow of the first electrolyte from the inlet port **202** to the fourth quadrant **218**.

[0039] The first inlet **204** and the third inlet **208** may include a first orifice **234** and a second orifice **236** respectively. The first and second orifices **234** and **236** may be disposed adjacent to a collection point of the first inlet **204** and the third inlet **208** respectively as shown in **FIG. 2C**. The first orifice **234** and the second orifice **236** may be adapted to restrict in flowrate in the first inlet **204** and the second inlet **206** such that the flow rates in the third inlet **208** and in the fourth inlet **210** are maintained.

[0040] In some aspects of the present disclosure, the second inlet **206** and the fourth inlet **210** may include wide passages respectively, such that the flow rate of the first electrolyte in the second quadrant **214** and the fourth quadrant **218** are maintained concerning the flow rate of the first electrolyte in the first quadrant **212** and the third quadrant **216**.

[0041] Each quadrant of the first quadrant **212**, the second quadrant **214**, the third quadrant **216**, and the fourth quadrant **218** may include a serpentine-like flow channel. The serpentine-like flow channels are variable in length with a split in transverse length from inlet to outlet.

[0042] The drain canal **220** may be adapted to collect the first electrolyte from each quadrant of the first quadrant **212**, the second quadrant **214**, the third quadrant **216**, and the fourth quadrant **218**. The drain canal **220** may further be adapted to pass the collected first electrolyte to the outlet port **222**.

[0043] The outlet port **222** may be coupled with an outlet tube of the first electrolyte tank. The flow field plate**102** may further include a first wall rib **224**, a second wall rib **226**, a third wall rib **228**, a fourth wall rib **230**, and a fifth wall rib **232**.

[0044] The first wall rib **224** may be disposed between the first quadrant **212** and the third quadrant **216**. The second wall rib **226** may be disposed between the first quadrant **212** and the second quadrant **214**. The third wall rib **228** may be disposed between the third quadrant **216** and the fourth quadrant **218**.

[0045] The fourth wall rib **230** and the fifth wall rib **232** may be disposed in a parallel configuration with each other and the parallel configuration is disposed between the second quadrant **214** and the fourth quadrant **218** as shown in **FIG. 2D**. In some aspects of the present disclosure, the thickness of the fourth wall rib **230** and the fifth wall rib **232** may gradually decrease from the outlet corner as represented by reference numerals **238**,**240** and **242** of **FIG. 2D**. In some aspects of the present disclosure, the change in the thickness reduces an unfavourable pressure drop of the first electrolyte. In some aspects of the present disclosure, the thickness of the fourth wall rib **230** and the fifth wall rib **232** may be constant for short channels. In some aspects of the present disclosure, the set of plates **100** may be disposed in the battery pack system (not shown).

[0046] In some aspects of the present disclosure, a method of working of the set of plates **100** may include the following steps: receiving, by way of the inlet port **202**, first electrolyte; distributing, by way of the first inlet **204**, the second inlet **206**, the third inlet **208**, and the fourth inlet **210**, the received first electrolyte; passing,

by way of the first quadrant **212**, the second quadrant **214**, the third quadrant **216**, the fourth quadrant **218**, the distributed first electrolyte; and collecting, by way of the drain canal **220**, the first electrolyte.

[0047] The foregoing discussion of the present disclosure has been presented for purposes of illustration and description. It is not intended to limit the present disclosure to the form or forms disclosed herein. In the foregoing Detailed Description, for example, various features of the present disclosure are grouped in one or more aspects, configurations, or aspects for the purpose of streamlining the disclosure. The features of the aspects, configurations, or aspects may be combined in alternate aspects, configurations, or aspects other than those discussed above. This device of disclosure is not to be interpreted as reflecting an intention the present disclosure requires more features than are expressly recited in each claim.

[0048] Moreover, though the description of the present disclosure has included description of one or more aspects, configurations, or aspects and certain variations and modifications, other variations, combinations, and modifications are within the scope of the present disclosure, e.g., as may be within the skill and knowledge of those in the art, after understanding the present disclosure. It is intended to obtain rights that include alternative aspects, configurations, or aspects to the extent permitted, including alternate, interchangeable, and/or equivalent structures, functions, ranges, or steps to those claimed, whether or not such alternate, interchangeable, and/or equivalent structures, functions, ranges or steps are disclosed herein, and without intending to publicly dedicate any patentable subject matter.

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CLAIMS

We Claim:

1. A flow field plate **102** comprising:

an inlet port **202** configured to receive a first electrolyte;

a first inlet **204**, a second inlet **206**, a third inlet **208**, and a fourth inlet **210**, each fluidly connected to the inlet port **202**, and configured to distribute the first electrolyte to a first quadrant **212**, a second quadrant **214**, a third quadrant **216**, and a fourth quadrant **218**, respectively;

a drain canal **220** configured to collect a reacted first electrolyte from each of the a first quadrant **212**, a second quadrant **214**, a third quadrant **216** and a fourth quadrant **218**; and

an outlet port **222** fluidly connected to the drain canal **220**, and configured to discharge the reacted first electrolyte.

2. The flow field plate of claim 1, wherein each of the first quadrant **212**, a second quadrant **214**, a third quadrant **216**, and a fourth quadrant **218** comprise a serpentine flow channel.

3. The flow field plate of claim 2, wherein the serpentine flow channels are variable in length with a split in transverse length from inlet to outlet.

4. The flow field plate of claim 1, wherein the first inlet **204** and the third inlet **208** each comprise an orifice **234, 236** configured to restrict flow rate.

5. The flow field plate of claim 1, wherein the second inlet **206** and the fourth inlet **210** comprise widened passages configured to maintain a flow rate of the first electrolyte.

6. The flow field plate of claim 1, further comprising:

a first wall rib **224** disposed between the first quadrant and the third quadrant;

a second wall **226** rib disposed between the first quadrant and the second quadrant;

a third wall rib **228** disposed between the third quadrant and the fourth quadrant;

a fourth wall rib **230**; and

a fifth wall rib **232**;

wherein the fourth wall rib **230** and the fifth wall rib **232** are disposed in a parallel configuration between the second quadrant **214** and the fourth quadrant **218**.

7. The flow field plate of claim 6, wherein a thickness of the fourth wall rib **230** and the fifth wall rib **232** gradually decreases from the outlet port.

8. A flow battery system comprising:

a flow field plate **102** according to claim 1;

a current collector **104** disposed adjacent to a first side **118** of the flow field plate **102** ;

a graphite felt electrode **106** disposed adjacent to a second side **120** of the flow field plate **102**;

a polymer membrane **114**; and

a flow frame **110**.

9. The flow battery system of claim 8, further comprising:

an insulated plate disposed adjacent to the current collector; and

a compressible gasket disposed adjacent to the graphite felt electrode.

10. A method of operating a flow battery system, comprising:

receiving a first electrolyte at an inlet port of a flow field plate;

distributing the first electrolyte from the inlet port to a first quadrant, a second quadrant, a third quadrant, and a fourth quadrant of the flow field plate via a first inlet, a second inlet, a third inlet, and a fourth inlet, respectively;

flowing the first electrolyte through serpentine flow channels within each of the first quadrant, the second quadrant, the third quadrant, and the fourth quadrant;

collecting a reacted first electrolyte from each of the first quadrant, the second quadrant, the third quadrant, and the fourth quadrant at a drain canal of the flow field plate; and

discharging the reacted first electrolyte from the drain canal through an outlet port of the flow field plate.

11. A set of plates **100** for a battery pack system, the battery pack system comprising:

a flow field plate **102** with a plurality of channels to facilitate the circulation of a first electrolyte;

a current collector **104** disposed adjacent to a first side **118** of the flow field plate **102**, enabling the flow of electrons from the first electrolyte to an external electrode while discharging and enabling flow of electrons to the first electrolyte to an external electrode while charging;

a graphite felt electrode **106** disposed adjacent to a second side **120** of the flow field plate **102**, adapted to prevent electron flow to the second side, such that electrons pass only through the current collector **104** wherein the graphite felt electrode **106** enables the first electrolyte to flow across the flow field plate **102**, being a non-porous and non-permeable frame having electrical conductivity of magnitude 10^4 microsiemens per centimetre (μs/cm);

an insulated plate **108** disposed adjacent to the current collector **104** to provide mechanical strength and support to the set of plates **100**;

a flow frame **110** disposed adjacent to the graphite felt electrode **106**, the flow frame **110** adapted to restrict the flow of the first electrolyte by providing a sealing effect and bind flow field in the flow field plate **102;**

a compressible gasket **112** disposed adjacent to the flow frame **110**, seal each cell of the set of plates **100** and compress the graphite felt electrode **106** with the flow frame **110** for performance; and

a polymer membrane **114** disposed adjacent to the compressible gasket **112** to prevent cross-mixing of the first

electrolyte with a second electrolyte and prevent a short circuit with the set of plates **100** during transfer of ions to complete a circuit for the flow of current.

12. The set of plates **100** of for a battery pack system of claim 11, wherein the flow field plate **102** includes an inlet port **202** coupled with an input tube of a first electrolyte tank, the inlet port **202** is connected with a first inlet **204,** wherein

the first inlet **204** facilitates the flow of the first electrolyte from the inlet port **202** to a first quadrant **212**,

a second inlet **206** wherein the first second inlet **204** facilitates the flow of the first electrolyte from the inlet port **202** to a second quadrant **214**,

a third inlet **208** wherein the third inlet **208** facilitates the flow of the first electrolyte from the inlet port **202** to a third quadrant **216** and

a fourth inlet **210** wherein the fourth inlet **210** facilitates flow of the first electrolyte from the inlet port **202** to the fourth quadrant **218**,

to distribute the first electrolyte across the flow field **102**.

13. The set of plates **100** of for a battery pack system of claim 2, wherein

the first inlet **204** and the third inlet **208** include a first orifice **234** and a second orifice **236** respectively, which are disposed adjacent to a collection point of the first inlet **204** and the third inlet **208** respectively,

wherein the first orifice **234** and the second orifice **236** restrict in flowrate in the first inlet **204** and the second inlet **206** such that

the flow rates in the third inlet **208** and in the fourth inlet **210** are maintained.

14. The set of plates **100** of for a battery pack system of claim 3,wherein

the second inlet **206** and the fourth inlet **210** have passages such that the flow rate of the first electrolyte in the second quadrant **214** and the fourth quadrant **218** are maintained with respect to the flow rate of the first electrolyte in the first quadrant **212** and the third quadrant **216**, wherein

each of the first quadrant **212**, the second quadrant **214**, the third quadrant **216**, and the fourth quadrant **218** include a serpentine-like flow channel being variable in length with a split in transverse length from inlet to outlet.

15. The set of plates **100** of for a battery pack system of claim 4, further comprising:

the flow field **102** having a drain canal **220** to collect the first electrolyte from each of the first quadrant **212**, the second quadrant **214**, the third quadrant **216**, and the fourth quadrant **218**, and pass the collected first electrolyte to the outlet port **222**.

16. The set of plates **100** of for a battery pack system of claim 15:

wherein the flow field plate**102** further includes a first wall rib **224**, a second wall rib **226**, a third wall rib **228**, a fourth wall rib **230**, and a fifth wall rib **232** to separate the quadrants, wherein

the first wall rib **224** separates the first quadrant **212** and the third quadrant **216**,

the second wall rib **226** separates the first quadrant **212** and the second quadrant **214**,

the third wall rib **228** separates the third quadrant **216** and the fourth quadrant **218**, and

the fourth wall rib **230** and the fifth wall rib **232** are in a parallel configuration with each other and the parallel configuration is disposed between the second quadrant **214** and the fourth quadrant **218**, wherein

the thickness of the fourth wall rib **230** and the fifth wall rib **232** gradually decreases from the outlet corner and the change in the thickness reduces pressure drop of the first electrolyte,

the thickness of the fourth wall rib **230** and the fifth wall rib **232** is constant for short channels.

17. A method of operating a set of plates **100** for a battery pack system of claim 11: comprising:

receiving a first electrolyte through the inlet port **202**;

distributing the first electrolyte through the first inlet **204**, the second inlet **206**, the third inlet **208**, and the fourth inlet **210** across the flow field plate **102**;

passing the distributed first electrolyte through the first quadrant **212**, the second quadrant **214**, the third quadrant **216**, and the fourth quadrant **218** of the flow field plate **102**; and

collecting the first electrolyte via a drain canal **220** and directing it to the outlet port **222**.

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