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(54) **BATTERY CELL ARRAY TO PACK THERMAL RUNAWAY GAS VENTING SYSTEM USING MID PACK CHANNEL SYSTEM**

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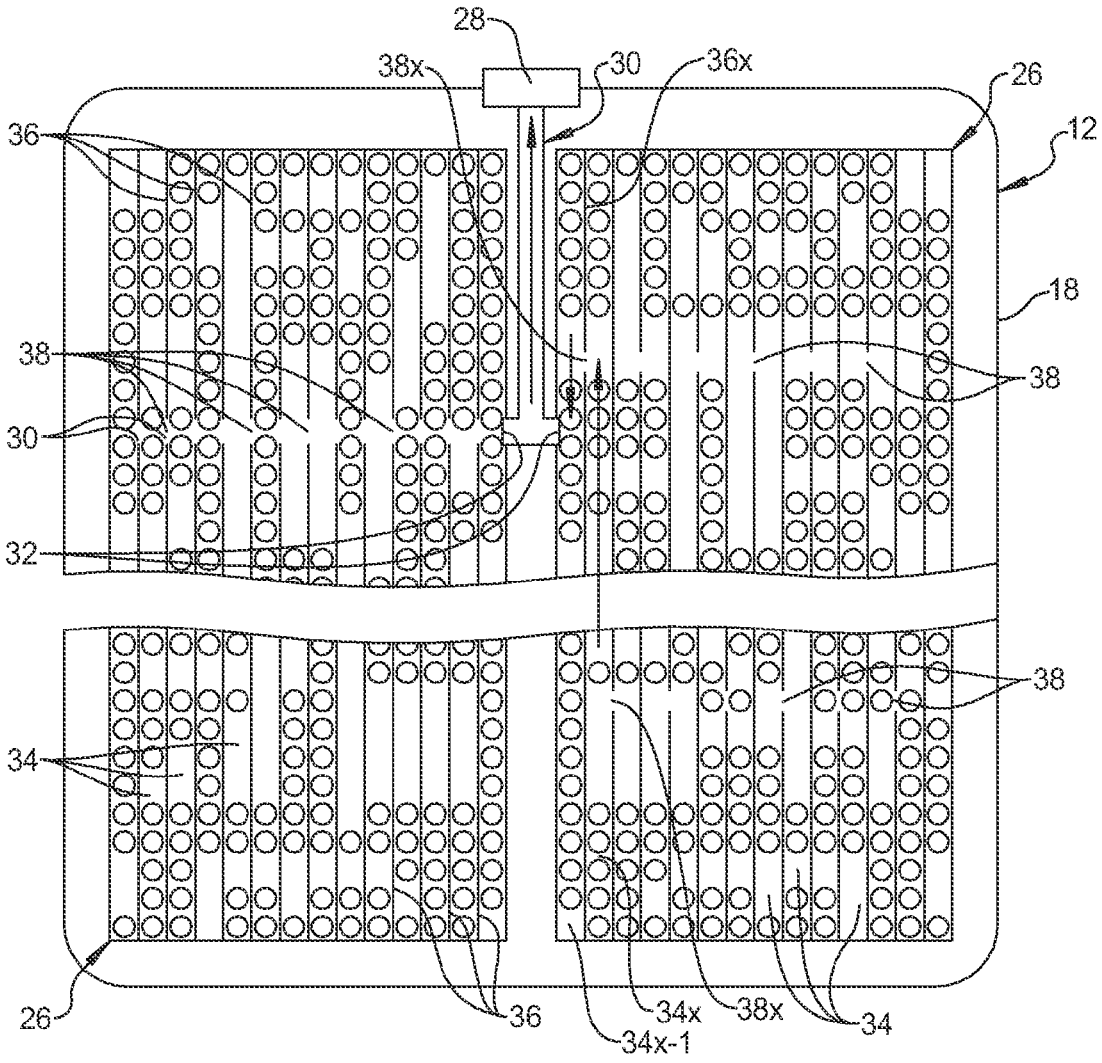
(57) **ABSTRACT**

A battery pack for a vehicle includes a housing including at least one pack vent between an interior and an exterior of the housing. A plurality of battery cells are disposed within the housing. A channel system includes channel arrays positioned in connection with vents on each of the plurality of battery cells and the channel arrays are in connection with a master channel that communicates with the at least one pack vent, wherein the channel system is enclosed from the rest of the volume of the pack.



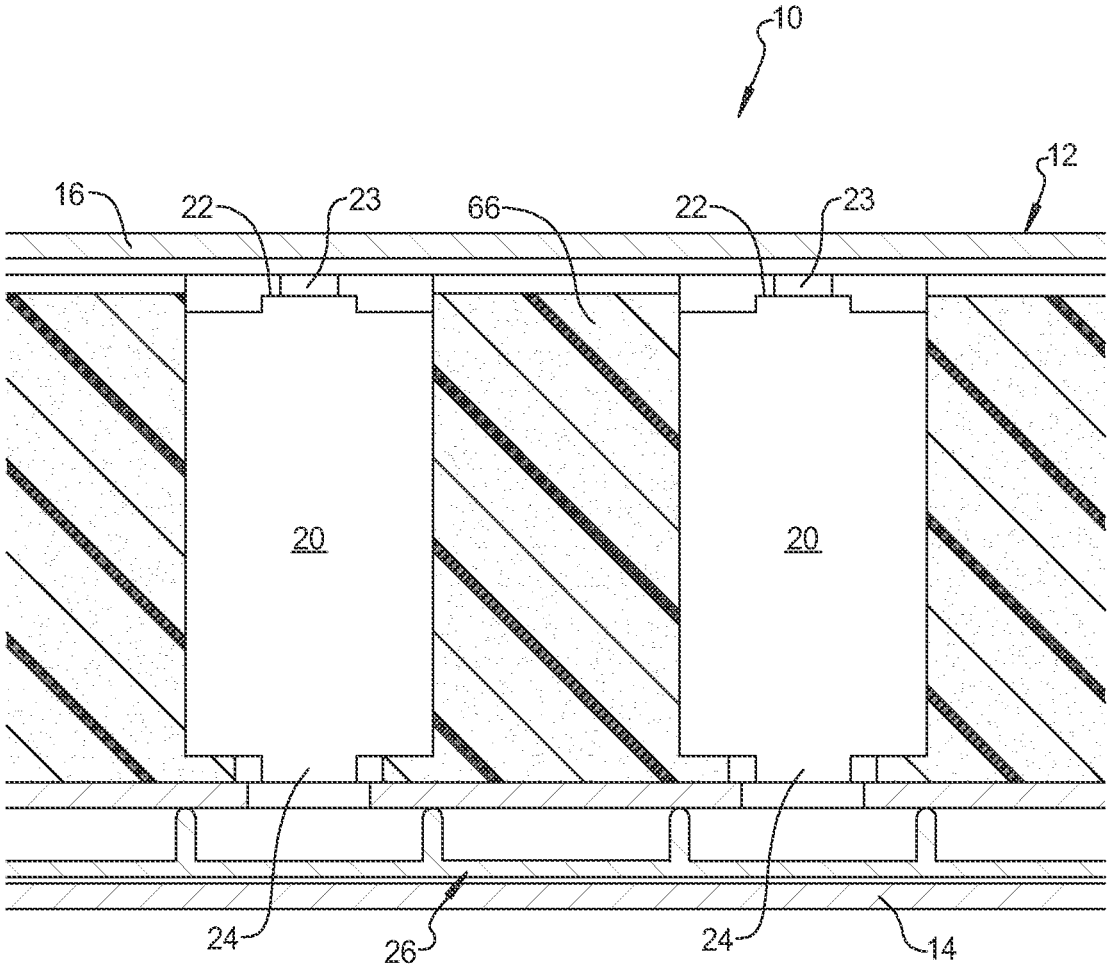


FIG. 1

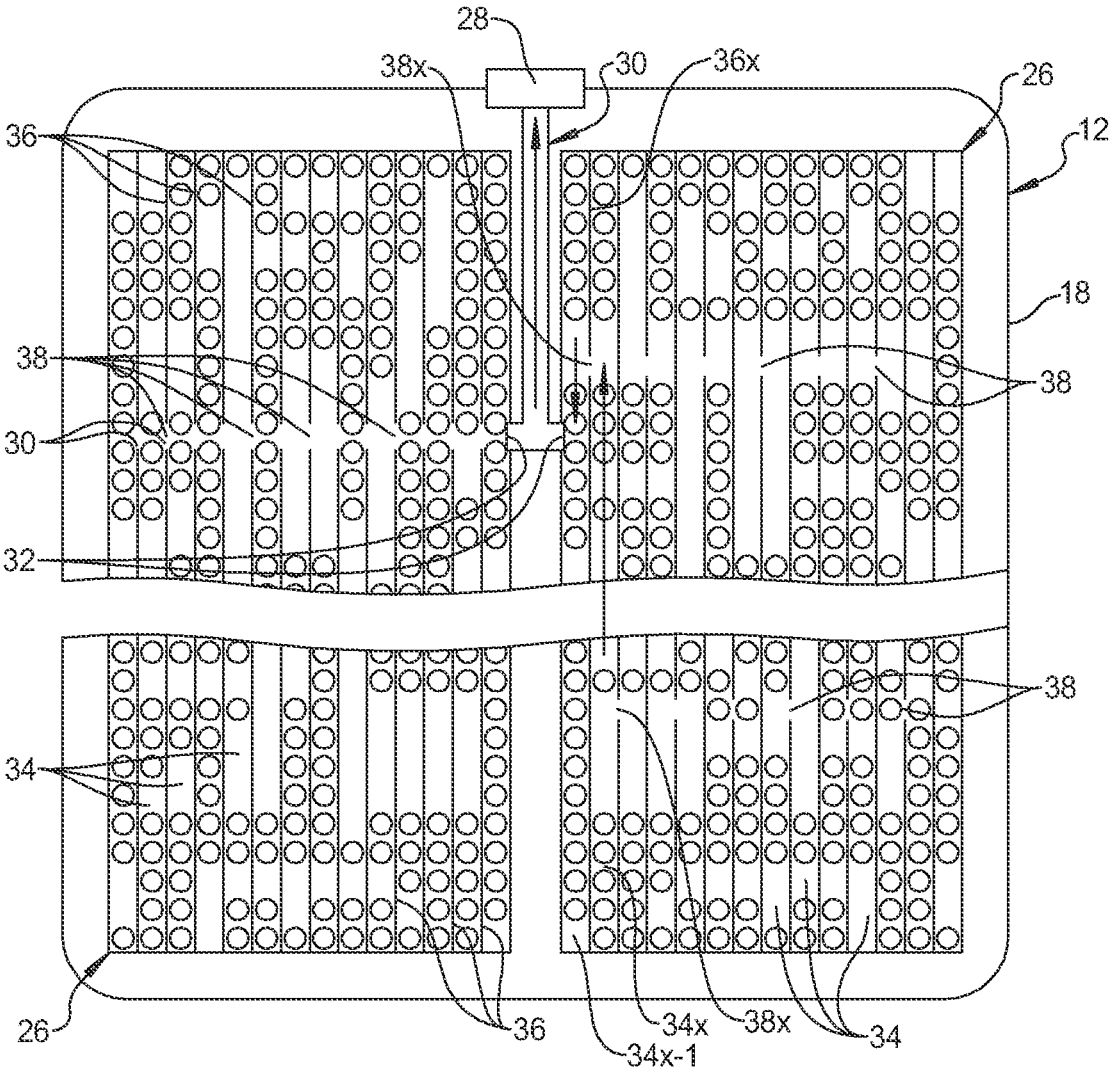


FIG. 2

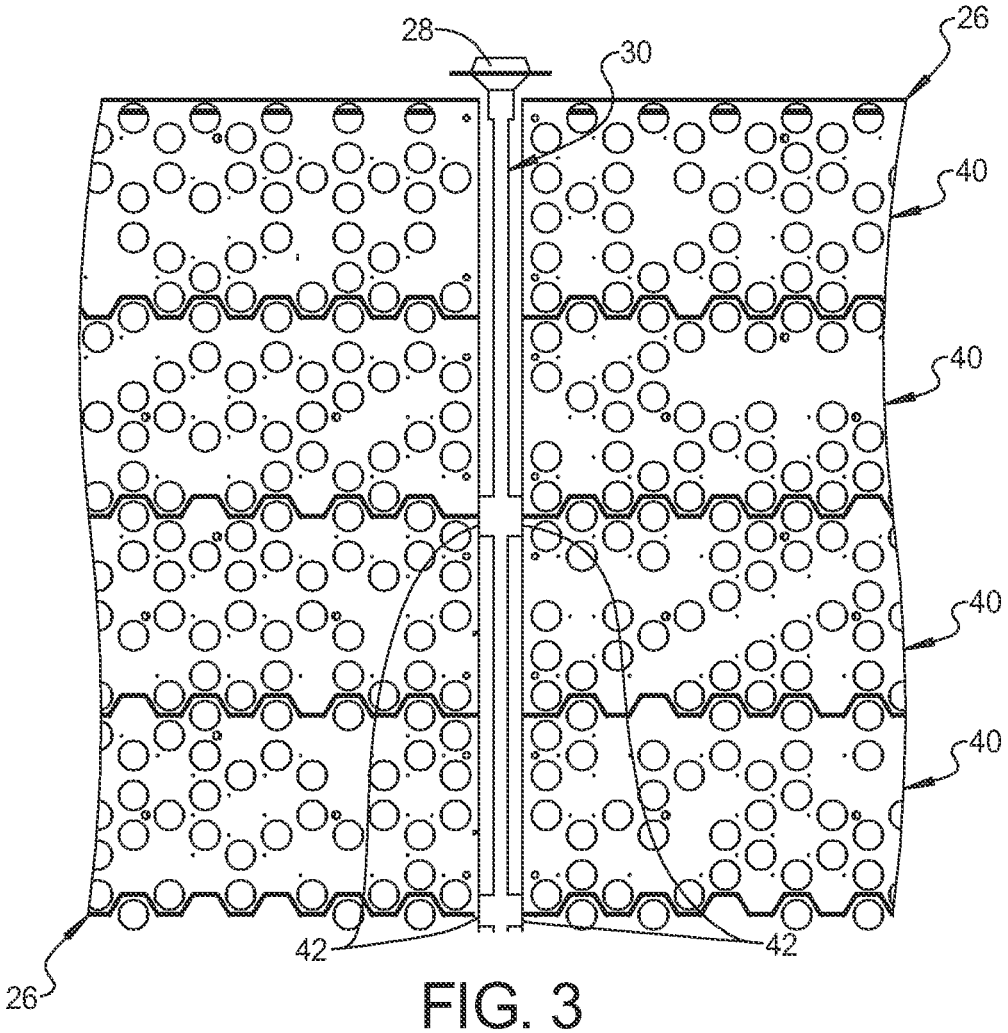


FIG. 3

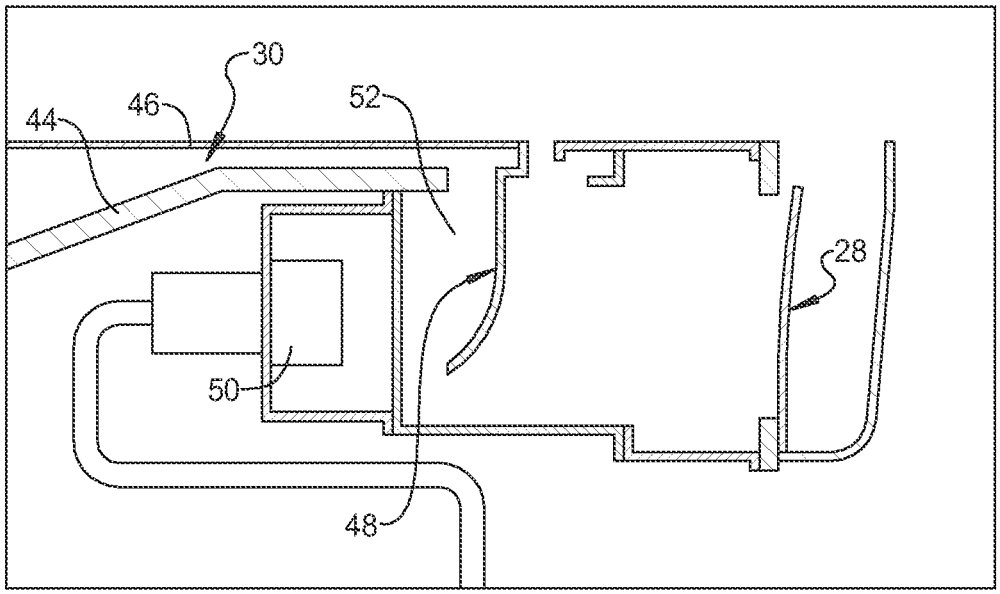


FIG. 4

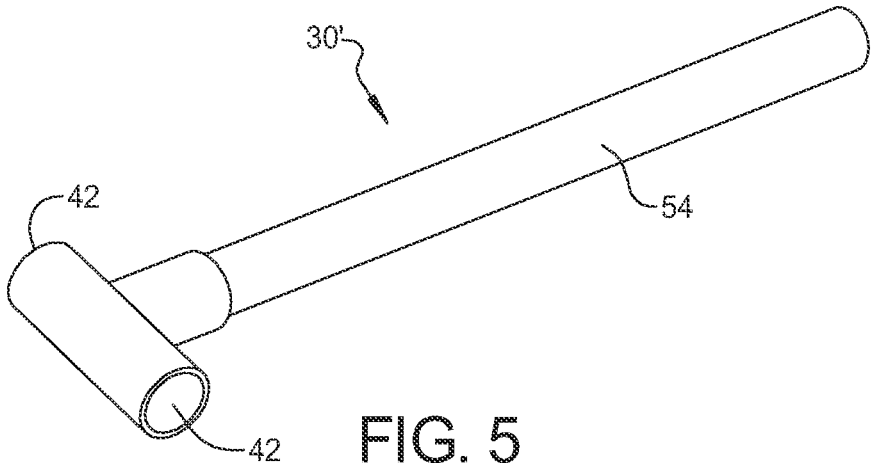


FIG. 5

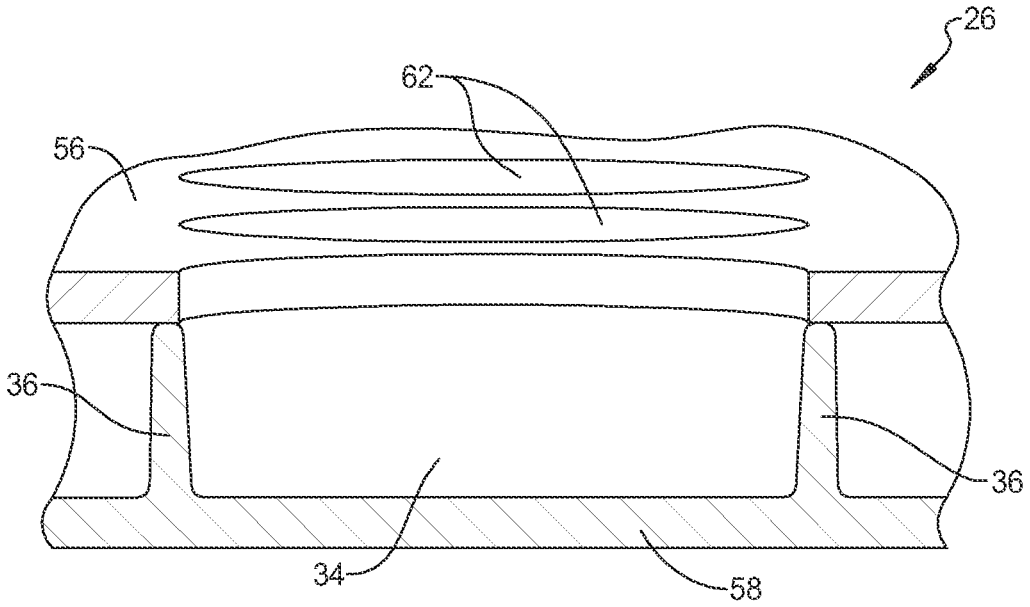


FIG. 6

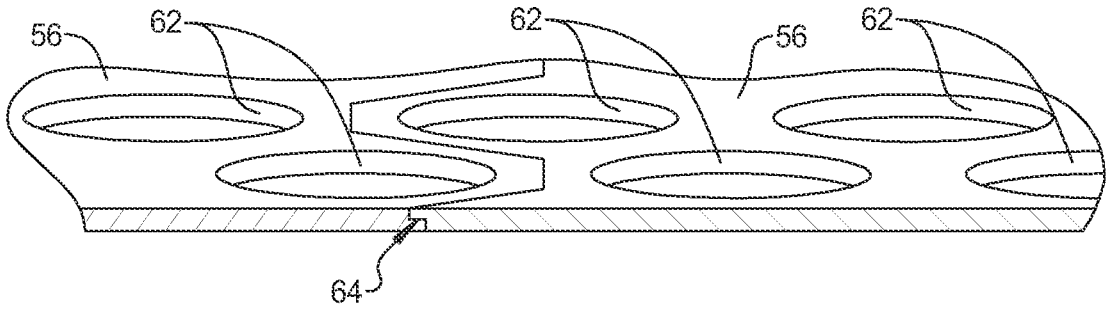


FIG. 7

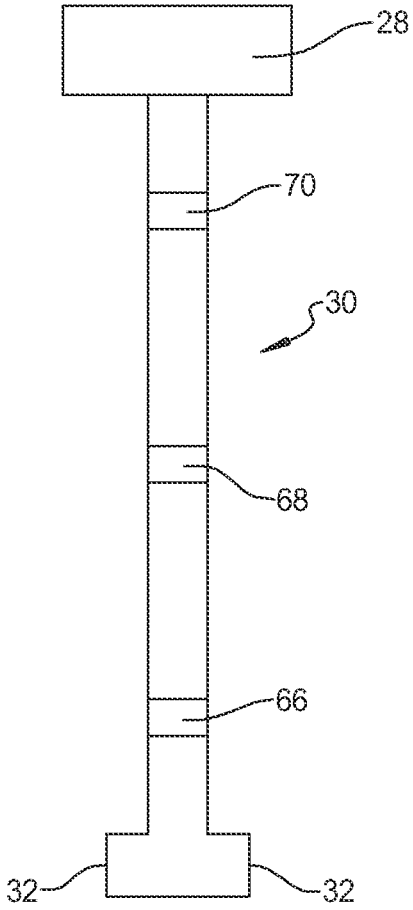


FIG. 8

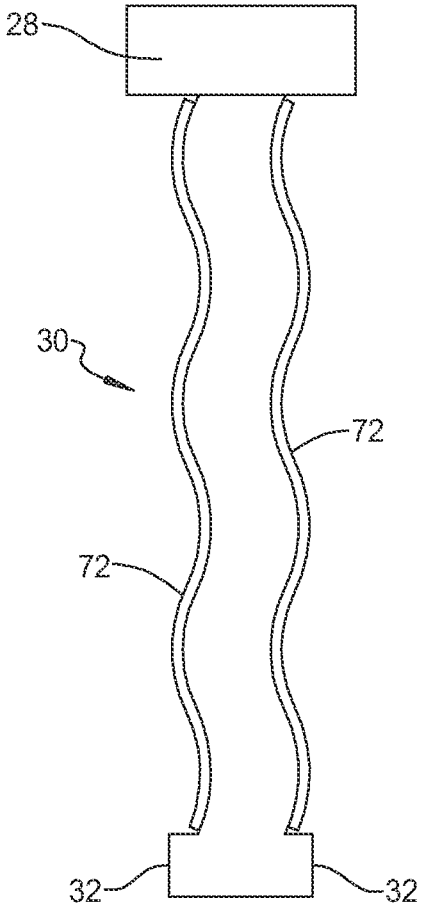


FIG. 9

BATTERY CELL ARRAY TO PACK THERMAL RUNAWAY GAS VENTING SYSTEM USING MID PACK CHANNEL SYSTEM

INTRODUCTION

[0001] The information provided in this section is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0002] Ventilating the battery cells of a battery pack for an electric vehicle is known in the art. The vent system must remain open for gas to traverse during a thermal event so that the gas is able to reach the pack's vent port. The rest of the pack is commonly filled with potting resin (foamed or non-foamed) for electrical isolation, structural performance and thermal insulation. Controlling the position of the potting is challenging. The variability of foam expansion makes the baseline system incompatible with foam potting.

[0003] The present disclosure relates to a battery cell array to pack thermal runaway gas venting system using mid pack channel system.

SUMMARY

[0004] The main objective of the present disclosure is to create a closed volume for the thermal runaway gas vent system. This closed volume cannot be blocked by potting during manufacturing.

[0005] According to an aspect of the present disclosure, a battery pack for a vehicle includes a housing including at least one pack vent between an interior and an exterior of the housing. A plurality of battery cells are disposed within the housing. A channel system includes channel arrays positioned in connection with vents on each of the plurality of battery cells and the channel arrays are in connection with a master channel that communicates with the at least one pack vent, wherein the channel system is enclosed from the rest of the volume of the pack.

[0006] According to a further aspect, the housing contains a potting material encapsulating the channel system.

[0007] According to a further aspect, the potting material is one of a foam, and a non-foamed polymeric resin.

[0008] According to a further aspect, the channel system is isolated to prevent potting from entering the vent system.

[0009] According to a further aspect, the channel array includes a plurality of battery cell engagement panels and a plurality of tray panels.

[0010] According to a further aspect, a gap between the adjacent battery cell engagement panels and the adjacent tray panels is less than half a thickness of the battery cell engagement panels and the tray panels, respectively.

[0011] According to a further aspect, the master channel includes multiple master channels.

[0012] According to a further aspect, the at least one pack vent includes multiple pack vents.

[0013] According to a further aspect, the housing includes a plurality of submodules and each submodule includes a channel array.

[0014] According to a further aspect, the channel array include ribs defining a plurality of channels under the cells that run either longitudinal or transverse to the vehicle and are connected by a series of openings in the ribs.

[0015] According to a further aspect, a thermal runaway sensor is in the master channel.

[0016] According to a further aspect, the master channel connects with the channel arrays along a face of the array.

[0017] According to a further aspect, the master channel runs down a center of the housing dividing separate sections of the housing.

[0018] According to a further aspect, the master channel is formed by a hose that connects the channel array to the at least one pack vent.

[0019] According to a further aspect, the master channel is formed directly in the potting such that there is no separate wall material.

[0020] According to a further aspect, the master channel contains a series of spark arrestors with decreasing hole size as the gas travels towards the pack vent.

[0021] According to a further aspect, at least one cooling element is disposed along the master channel.

[0022] According to a further aspect, the channel system includes a plurality of battery cell engagement panels and a plurality of tray panels that include ribs defining the channel arrays and a plurality of apertures in the battery cell engagement panels and in communication with vents in the plurality of battery cells.

[0023] According to a further aspect, a breakable sheet is disposed between the plurality of battery cell engagement panels and the plurality of tray panels.

[0024] According to another aspect, a battery pack for a vehicle includes a housing including at least one vent between an interior and an exterior of the housing. a plurality of battery cells are disposed within the housing. A channel system includes channel arrays positioned in connection with vents on each of the plurality of battery cells and the channel arrays are in connection with a master channel that communicates with the at least one pack vent of the housing. At least one cooling element is adjacent to the master channel.

[0025] Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims and the drawings. The detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0027] FIG. **1** is a partial cross-sectional view of a battery pack having a vent system according to the principles of the present disclosure;

[0028] FIG. **2** is a schematic view of a battery pack having a vent system with a channel array connecting each battery cell to a master channel;

[0029] FIG. **3** is a detailed view of the connection between the channel array and the master channel;

[0030] FIG. **4** is a perspective cut-away view of the master channel of the battery pack vent system;

[0031] FIG. **5** is a perspective view of an alternative tubing forming the master channel of the battery pack vent system;

[0032] FIG. **6** is a cross-sectional view of the cell tray of the channel array;

[0033] FIG. **7** is a cross sectional view of the interface between adjacent cell trays;

[0034] FIG. **8** is a schematic view of the spark arrestors disposed along the master vent channel; and

[0035] FIG. **9** is a schematic view of cooling ribbons disposed along the master vent channel.

[0036] In the drawings, reference numbers may be reused to identify similar and/or identical elements.

DETAILED DESCRIPTION

[0037] With reference to FIG. **1**, a battery pack **10** is schematically shown including a housing **12** having a bottom shear plate **14**, a top shear plate **16** and a sidewall enclosure **18** (see FIG. **2**). A plurality of battery cells **20** are disposed within the housing **12**. The battery cells **20** each include electric terminals **22** for connection to a bus bar or other system **23** for electrical connection. The battery cells **20** each include a vent **24** in communication with a channel array **26**.

[0038] As shown in FIG. **2**, the channel array **26** connects the vent **24** of each of the battery cells **20** to a pack vent **28** provided in the housing **12** via a master channel **30** that connects an outlet port **32** of the channel array **26** with the pack vent **28**. The channel array **26** includes a plurality of channels **34** separated by a series of ribs **36** that include openings **38** for communicating the vent **24** of each battery cell **20** with the outlet port **32** of the channel array **26**.

[0039] By way of example, as shown in FIG. **2**, the vent from the battery cell **20***x* communicates through a channel **34***x*, through opening **38***x* in rib **36***x* and to channel **34***x*-**1** to the outlet port **32** as indicated by the direction arrows. As shown in FIG. **2**, the ribs **36** include openings **38** to allow the vent **24** of each battery cell **20** to communicate through and across the channels **34** to the outlet port **32**. The channels **34** and the openings **38** can be provided with numerous alternative arrangements for communicating gasses from the battery cells **20** to the outlet port **32**. The system easily enables a longer gas travel path to enable the gas temperature to be reduced prior to the gas exiting the pack.

[0040] With reference to FIG. **3**, a plan view of the channel array **26** is shown being made up of interlocking channel panels **40** that interlock with adjacent channel panels **40** and communicate each battery cell to one of multiple outlet ports **32** that communicate with the master channel **30** at multiple inlet ports **42** along the master channel **30**.

[0041] With reference to FIG. **4**, the master channel **30** can be formed by a bottom part **44** and a top part **46** that engage one another to define the master channel **30** therebetween and communicate with an optional gas deflector **48** that can direct the vented gasses toward a thermal sensor **50** in a vent gas path **52**. The pack vent **28** is disposed at an end of the vent gas path **52**. The master channel **30** may be circular or non-circular in cross section. The master channel **30** may be a hose with a defined wall material, or may be molded into the potting using a tool. The tool could be a rigid, reusable mold or a removable flexible inflatable bladder.

[0042] With reference to FIG. **5**, the master channel **30'** can be made from a tube structure **54** that can have a circular, oval, rectangular, square or other cross-section. The tube structure includes a pair of inlet ports **42** that connect to the channel arrays **26**.

[0043] With reference to FIG. **6**-**7**, the channel array **26** is shown including battery cell engagement panels **56** and tray panels **58** that combine to define the channels **34** therebetween. The battery cell engagement panels **56** and the tray panels **58** can be formed as injection molded parts. A breakable sheet **60** may be added under the battery cell engagement panels **56** to thermally shield the rest of the cells during a thermal runaway event of the single cell. Sealant may be added to help hold the breakable sheet **60** in place. The breakable sheet **60** may be made from mica, phenolic, or another thermally resilient but brittle material that is breakable in response to a thermal event of a battery cell **20**. The battery cell engagement panels **56** include apertures **62** that communicate with a vent opening of each battery cell **20**. One of the battery cell engagement panels **56** and the tray panels **58** include the ribs **36** for defining the channels **34** of the channel array **26** that communicate each aperture **62** to the outlet port **32**. The ribs **36** can be sealed to the opposing one of the battery cell engagement panel **56** or the tray panel **58** to provide sealed channels **34**. In addition, as shown in FIG. **7**, a scarf joint **64** is provided at an interface of the adjacent battery cell engagement panels **56**. A gap between the scarf joint **64** is less than one half a thickness of the battery cell engagement panel **56** (generally less than 2-3 mm). The battery pack **10** is at least partially filled with potting **66**, as shown in FIG. **1**. The scarf joint **64** prevents the potting **66** from entering the cell channel array **26**. The joint **64** may be further sealed with a sealant or tape.

[0044] The entire vent system is sealed such that the potting **66** cannot enter the system during manufacture. With the channels **34** being sealed, the foam or non-foam potting **66** can be filled to a point that it contacts the upper and lower shear plates **14**, **16**, enabling upper-to-lower shear plate connection through the potting **66**. Once the potting is in place the vent system is sealed sufficiently to contain gas. In another variant, each section of cells could have its own or multiple master channels **30** connected to more than one separate pack vents **28**.

[0045] With reference to FIG. **8**, the master channel **30** is shown including inlet ports **42** that are configured to be connected to the outlet ports **32** of the channel arrays **26**. The master channel **30** can include a series of spark arrestors **66**, **68**, **70** that can filter out sparks passing through the master channel. The spark arrestors can be formed as a mesh having progressively smaller holes along the flow direction. The transition from large spark arrestors to refined spark arrestors give improved particle filtering which results in higher vent gas auto-ignition temperature s external to the pack providing increased allowable temperature of vent gas safely exiting the rechargeable energy storage system. The separation of spark arrestors from the pack vent **28** enable less restriction through the pack vent **28**, thus providing an increased flow rate, which results in potential reduction of a size or a number of pack level vents required.

[0046] With reference to FIG. **9**, the master channel **30** can be cooled using a cooling element such as a cooling ribbon **72** facing the master channel **30** to reduce the temperature of the gasses expelled from the pack vent **28**.

[0047] The battery pack **10** includes a closed ventilation system for transporting and reducing the temperature of discharged gas from a cell undergoing thermal runaway. The purpose of creating this closed system is to ensure potting **66** used to encapsulate the battery cells **20** does not enter the vent system during manufacturing of the battery pack **10**, as well as keep hot vent gases contained and away from the remaining battery cells **20**.

[0048] The foregoing description is merely illustrative in nature and is in no way intended to limit the disclosure, its application, or uses. The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims. It should be understood that one or more steps within a method may be executed in different order (or concurrently) without altering the principles of the present disclosure. Further, although each of the embodiments is described above as having certain features, any one or more of those features described with respect to any embodiment of the disclosure can be implemented in and/or combined with features of any of the other embodiments, even if that combination is not explicitly described. In other words, the described embodiments are not mutually exclusive, and permutations of one or more embodiments with one another remain within the scope of this disclosure.

[0049] Spatial and functional relationships between elements (for example, between modules, circuit elements, semiconductor layers, etc.) are described using various terms, including "connected," "engaged," "coupled," "adjacent," "next to," "on top of," "above," "below," and "disposed." Unless explicitly described as being "direct," when a relationship between first and second elements is described in the above disclosure, that relationship can be a direct relationship where no other intervening elements are present between the first and second elements, but can also be an indirect relationship where one or more intervening elements are present (either spatially or functionally) between the first and second elements. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A OR B OR C), using a non-exclusive logical OR, and should not be construed to mean "at least one of A, at least one of B, and at least one of C."

What is claimed is:

1. A battery pack for a vehicle, comprising:
- a housing including at least one pack vent between an interior and an exterior of the housing;
- a plurality of battery cells disposed within the housing; and
- a channel system including channel arrays positioned in connection with vents on each of the plurality of battery cells and the channel arrays are in connection with a master channel that communicates with the at least one vent of the housing, wherein the channel system is enclosed from the rest of the volume of the pack.

2. The battery pack for a vehicle according to claim **1**, wherein the housing contains a potting material encapsulating the channel system.

3. The battery pack for a vehicle according to claim **2**, wherein the potting material is one of a foam, and a non-foamed polymeric resin.

4. The battery pack for a vehicle according to claim **1**, wherein the channel system is isolated to prevent potting from entering the vent system.

5. The battery pack for a vehicle according to claim **1**, wherein the channel array includes a plurality of battery cell engagement panels and a plurality of tray panels.

6. The battery pack for a vehicle according to claim **5**, wherein a gap between the adjacent battery cell engagement panels and the adjacent tray panels is less than half a thickness of the battery cell engagement panels and the tray panels, respectively.

7. The battery pack for a vehicle according to claim **1**, wherein the master channel includes multiple master channels.

8. The battery pack for a vehicle according to claim **1**, wherein the at least one pack vent includes multiple pack vents.

9. The battery pack for a vehicle according to claim **1**, wherein the housing includes a plurality of sub-modules and each sub-module includes a channel array.

10. The battery pack for a vehicle according to claim **1**, wherein the channel array include ribs defining a plurality of channels under the cells that run either longitudinal or transverse to the vehicle and are connected by a series of openings in the ribs.

11. The battery pack for a vehicle according to claim **1**, further comprising a thermal runaway sensor in the master channel.

12. The battery pack for a vehicle according to claim **1**, wherein the master channel connects with the channel arrays along a face of the array.

13. The battery pack for a vehicle according to claim **1**, wherein the master channel runs down a center of the housing dividing separate sections of the housing.

14. The battery pack for a vehicle according to claim **1**, wherein the master channel is formed by a hose that connects the channel array to the at least one pack vent.

15. The battery pack for a vehicle according to claim **2**, wherein the master channel is formed directly in the potting such that there is no separate wall material.

16. The battery pack for a vehicle according to claim **1**, wherein the master channel contains a series of spark arrestors with decreasing hole size as the gas travels towards the pack vent.

17. The battery pack for a vehicle according to claim **1**, further comprising at least one cooling ribbon disposed along the master channel.

18. The battery pack for a vehicle according to claim **1**, wherein the channel system includes a plurality of battery cell engagement panels and a plurality of tray panels that include ribs defining the channel arrays and a plurality of apertures in the battery cell engagement panels and in communication with vents in the plurality of battery cells.

19. The battery pack for a vehicle according to claim **18**, further comprising a breakable sheet between the plurality of battery cell engagement panels and the plurality of tray panels.

20. A battery pack for a vehicle, comprising:
- a housing including at least one vent between an interior and an exterior of the housing;
- a plurality of battery cells disposed within the housing;
- a channel system including channel arrays positioned in connection with vents on each of the plurality of battery cells and the channel arrays are in connection with a master channel that communicates with the at least one pack vent of the housing; and
- at least one cooling element adjacent to the master channel.

* * * * *