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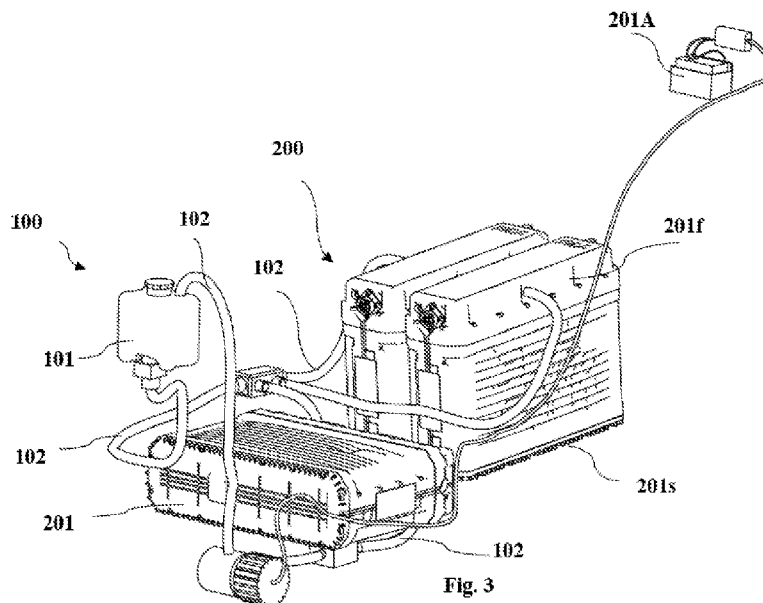


Fig. 3

(57) Abstract: The present subject matter relates to a thermal management system (100) for an energy storage system (200) and a method (500) thereof. The energy storage system (200) comprises one or more energy storage units (201). The thermal management system (100) comprises at least one storage member (101) to store a heat suppressing substance; one or more passages (102) to connect the at least one storage member (101) to the one or more energy storage units (201). A control member is configured to enable supply of the heat suppressing substance from the at least one storage member means (101) to the one or more energy storage units (201) via the one or more passages (102) to suppress heat generated in the one or more energy storage units (201) upon a detection of one or more predefined conditions.

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TITLE OF THE INVENTION**A THERMAL MANAGEMENT SYSTEM FOR AN ENERGY STORAGE
SYSTEM AND A METHOD THEREOF****TECHNICAL FIELD**

[0001] The present subject matter relates generally to a thermal management system for an energy storage system. More particularly, but not exclusively, the present subject matter relates to a thermal management system for an energy storage system of a vehicle.

BACKGROUND

[0002] Energy storage units have a plurality of cells in electrical connection with each other. During operation, each cell generates heat which is to be dissipated from the plurality of cells to ensure proper operation of the energy storage units without failing. Particularly, energy storage units, such as but not limited to Lithium-ion (Li-ion) energy storage units, have an issue of thermal runaway. For instance, when a cell, an area within the cell, or a plurality of cells of a Li-ion energy storage unit achieves an elevated temperature due to a thermal failure, a mechanical failure, internal or external short circuiting, or an electro-chemical abuse, a large amount of heat is generated. When the heat generated is larger than the heat dissipation, various side reactions between components inside the energy storage units are induced. This may cause further heat generation and consequently the pressure and the temperature of the energy storage units may increase sharply. This may lead to inflammation and/or explosion of the energy storage units. This process is referred to as thermal runaway.

[0003] Generally, in energy systems deploying multiple energy storage units like batteries, there is an imperative safety concern relating to reactions leading to the thermal runaway and fire propagation. The thermal management in electronic and electrical devices is the process of controlling the temperature and the pressure created therefrom of the device to ensure that it operates within a safe and optimal

range. These devices generate heat and/or pressure due to the flow of electricity through their circuits and components. If the heat is not dissipated effectively, it can damage the device or reduce its performance or worse cause fire leading to serious damage and/or injury.

5 [0004] Known thermal management in electronic devices involves several strategies, including heat sinks made of high thermal conductivity materials which are attached to the device using thermal interface materials like thermal paste or pads thereby helping in dissipating the heat by transferring it to a larger surface area. Other examples include integrated or externally forced air cooling systems
10 employing fans that are used to blow air over a heated surface of the device. These solutions are also costly considering costs associated with integration of heating pads, fins on the surface of energy storage units like batteries. Further, thermal interface materials are also known to be used for improving the thermal contact between surfaces by filling air gaps or surface imperfections. However, such
15 thermal interface materials may require additional coverings or casings which may add to the weight of the assembly and further involve associated manufacturing costs. Various other active cooling methods are also known to be used like those involving external energy power sources that include liquid cooling, and thermoelectric cooling. The passive cooling methods include natural convection,
20 radiation, and phase-change materials. All these are dependent on the heated surface being exposed to external air making them dependent on such ambient conditions which is not desirable in case of low relative wind speed, for example. However, in spite of the heavy costs and complexities including weight associated thereto, the thermal management systems known in the art are limited in applicability to general
25 cooling of the energy storage units during its operation, and fail to encompass aspects of thermal management in the event of thermal runaway occurring in the energy storage units.

[0005] Further, thermal management is a critical aspect of battery design and operation, as batteries can generate heat during charging and discharging.
30 Especially for large batteries, for example those used in electric as well as hybrid vehicles or involving high-power application machinery, excessive heat can lead to

reduced battery life, safety risks, and even failure or fire. Often thermal issues are managed by thermal management systems that use active or passive cooling methods to regulate battery temperature; redefining cell design with features like larger surface areas, thin or flexible substrates, and materials with high thermal conductivity that help manage temperature; electrolyte selection that can withstand higher temperatures; reducing battery charge/discharge rates; and thermal modeling which involves techniques to help battery designers predict and optimize temperature performance with the help of software to simulate heat flow and temperature gradients in different parts of the battery. Active methods discussed above, such as forced air cooling or other passive means such as electrolyte selection, high thermal conductivity materials etc. are either expensive or too complex to implement. This is especially true for markets that are cost sensitive or where the energy storage systems have limited space for installation.

[0006] Furthermore, various attempts have been made in the past which involve use of immersive cooling that involves circulation of the coolant along the battery pack surface or casing units with the help of internal tubing to mitigate fire hazards internally. Since, thermal runaways create a pressure build-up in battery housings, the pressure must be released quickly. If not, the risk of an explosion becomes a reality posing a serious hazard. Therefore, above known systems are largely preventive in nature but cannot effectively address a contingency where an actual thermal runaway or fire situation becomes a reality for an energy storage system where rapid cooling is required or rapid and safe expulsion of the excessive heat and pressure is needed to minimize damage or injury.

[0007] Therefore, there is a need to address the various aspects of battery safety pertaining to providing a system for circulation of a heat suppressant to not only act as a coolant but also a hydrant for fire mitigation in the event of thermal runaway in the battery pack.

[0008] The proposed invention addresses heat dissipation, effective heat transfer mechanism, thermal management at all condition, cooling of cell tab and surface condition, thermal protection for cells and battery module which only enhances towards all-purpose in the vehicle running condition as well as idle condition.

[0009] So, in providing a fire mitigation system in existing vehicles and high-power applications the proposed invention provides a novel and inventive thermal management system which is capable of deploying a heat suppressing mechanism operable during initial stages of thermal runaway and a heat suppressing fluid such as a fire hydrant supply assembly operable at later stages to prevent propagation of the fire from the battery.

SUMMARY OF THE INVENTION

[00010] The present invention to a thermal management system for an energy storage system and a method thereof. The energy storage system comprises one or more energy storage units. The thermal management system comprises at least one storage member which is configured to store a heat suppressing substance. The at least one storage member supplies the heat suppressing substance from the at least one storage member to the one or more energy storage units through one or more passages which connect the at least one storage member to the one or more energy storage units. A control member is configured to enable supply of the heat suppressing substance from the at least one storage member to the one or more energy storage units to suppress heat generated in the one or more energy storage units upon a detection of one or more predefined conditions. In one embodiment of the invention, an energy storage system is disclosed which has one or more energy storage units which can power an electrical load. In another aspect of the invention a vehicle is disclosed which has the energy storage system powering plurality of components of the vehicle. The thermal management system as mentioned above can be implemented as part of the energy storage system and/or the vehicle herein above. The present specification also discloses a method for thermal management in a vehicle. The method comprises the steps of monitoring and detecting one or more predefined conditions in the one or more energy storage units. The method also involves the step of supplying the heat suppressing substance from the at least one storage member to the one or more energy storage units through the one or more passages upon the detection of the one or more predefined conditions.

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BRIEF DESCRIPTION OF THE DRAWINGS

[00011] The details are described with reference to an embodiment of a thermal management system for an energy storage system along with the accompanying figures. The same numbers are used throughout the drawings to reference similar features and components.

5 [00012] **Figure 1** illustrates a side perspective view of a thermal management system for an energy storage system of a vehicle in one embodiment of the invention.

[00013] **Figure 2** illustrates a side perspective view of a thermal management system for an energy storage system with one or more collection units in one
10 embodiment of the invention.

[00014] **Figure 3** illustrates a side perspective view of a thermal management system for an energy storage system in one embodiment of the invention.

[00015] **Figure 4** illustrates a side perspective view of a thermal management system in one embodiment of the invention.

15 [00016] **Figure 5** illustrates a flowchart of the method of a thermal management system in one embodiment of the invention.

DETAILED DESCRIPTION

[00017] In order to achieve one or more of the above-mentioned objectives and
20 overcome the related problems, the present invention provides a thermal management system for heat suppressing and fire mitigation mechanism.

[00018] The present invention addresses heat dissipation in energy storage systems. The present subject matter provides an effective heat transfer mechanism to address concerns of thermal management at all operating conditions of energy storage
25 systems. In order to effectively dissipate heat from the energy storage systems, the present disclosure address cooling of cell tab in one or more energy storage units of the energy storage system as well as one or more surfaces of the one or more energy storage units. The present subject matter also provides thermal protection for cells, battery module, battery pack and overall protection of energy storage device.
30 Consequently, the present invention also achieves safety enhancement in the vehicle running condition as well as idle condition. Furthermore, the present

invention is also directed towards solving temperature raise problem by regulating temperature that is generated during energy storage system utilization event and at the same time ensure timely releasing of heat suppressing substance that can act as hydrant in case of extreme and sudden heat and pressure conditions. Thus, the thermal management achieves among other advantages as above, quick de-gassing and as well as fire mitigation functions.

[00019] As per one embodiment of the invention, a thermal management system for an energy storage system is disclosed. The energy storage system comprises one or more energy storage units. The thermal management system comprises at least one storage member to store a heat suppressing substance; a one or more passages being configured to connect the at least one storage member to the one or more energy storage units. The one or more passages are also configured to supply the heat suppressing substance from the at least one storage member to the one or more energy storage units. The thermal management system comprises a control member to enable supply of the heat suppressing substance from the at least one storage member to the one or more energy storage units to suppress heat generated in the one or more energy storage units upon a detection of one or more predefined conditions.

[00020] As per one embodiment of the invention, in the thermal management system, the one or more predefined conditions is a predefined level of at least one of a temperature and pressure in the one or more energy storage units. In another embodiment, the predefined level temperature being above 60 degrees Celsius in the one or more energy storage units.

[00021] As per one embodiment of the invention, in the thermal management system, the one or more energy storage units are configured to have a first portion and a second portion. The first portion and the second portion comprise a plurality of openings to vent out undesirable gas at high temperature and smoke generated inside the one or more energy storage units.

[00022] As per one embodiment of the invention, in the thermal management system, wherein the one or more passages comprises one or more inlet passages and one or more outlet passages.

[00023] As per one embodiment of the invention, in the thermal management system, wherein the at least one storage member is disposed at a higher elevation from ground than the one or more energy storage units. The one or more inlet passages of the one or more passages are connected to the first portion of the one or more energy storage units. Thus, the first portion is configured to serve as an entry point for the heat suppressing substance into the one or more energy storage units. The one or more outlet passages of the one or more passages are connected to the second portion to allow a discharge of the heat suppressing substance towards one or more collection units after suppressing the heat inside the one or more energy storage units. The one or more collection units are being disposed below the second portion to receive the heat suppressing substance. The one or more outlet passages are being configured to supply the heat suppressing substance from the one or more collection units back to the at least one storage member.

[00024] As per one embodiment of the invention, in the thermal management system, the at least one storage member is configured to have a solenoid valve. The solenoid valve is configured to be actuated by the control member upon the detection of the one or more predefined conditions of the one or more energy storage units, thereby allowing the thermal management system to supply the heat suppressing substance to the one or more energy storage units.

[00025] As per one embodiment of the invention, in the thermal management system, there are more than one energy storage units, the one or more inlet passages are configured to supply the heat suppressing substance from the at least one storage member to the one or more energy storage units via a first distribution member. The one or more outlet passages connects the one or more collection units to the at least one storage member via at least one pumping member and a second distribution member. The at least one pumping member is configured to pump the heat suppressing substance from the second distribution member to the at least one storage member.

[00026] As per one embodiment of the invention, in the thermal management system, the at least one pumping member is powered by an auxiliary energy storage unit and the control member being configured to control an operation of the at least

one pumping member to pump the heat suppressing substance from the one or more collection units back to the at least one storage member upon detection of the one or more predefined conditions of the one or more energy storage units.

[00027] In yet another embodiment of the invention, an energy storage system is disclosed. The energy storage system comprises one or more energy storage units being configured to supply an energy to one or more loads. The energy storage system also comprises a thermal management system. The thermal management system comprises at least one storage member to store a heat suppressing substance; one or more passages to connect the at least one storage member to the one or more energy storage units. The one or more passages is configured to supply the heat suppressing substance from the at least one storage member to the one or more energy storage units to suppress a heat generated in the one or more energy storage units. The thermal management system also comprises a control member which is being configured to enable supply of the heat suppressing substance from the at least one storage member to the one or more energy storage units upon a detection of one or more predefined conditions of the one or more energy storage units. The one or more predefined conditions can be at least one of predefined levels of a temperature and a pressure inside the one or more energy storage units.

[00028] As per one embodiment of the invention, in the energy storage system, a plurality of sensors is being disposed in the one or more energy storage units. The plurality of sensors is being configured to monitor the one or more predefined conditions of the one or more energy storage units. In another aspect of the invention), the one or more predefined conditions being at least one of predefined levels of a temperature and a pressure inside the one or more energy storage units.

[00029] As per one embodiment of the invention, in the energy storage system, the thermal management system is detachably attached to a frame assembly. The frame assembly is configured to mount the one or more energy storage units.

[00030] As per one embodiment of the invention, in the energy storage system, the one or more energy storage units comprises a first portion and a second portion. The first portion and the second portion comprise a plurality of openings. The

plurality of openings is configured to vent undesirable gases and smoke being generated from the one or more energy storage units.

[00031] As per one embodiment of the invention, in the energy storage system, the at least one storage member is connected to the first portion of the one or more energy storage units via the one or more passages such that the heat suppressing substance being supplied to the first portion through the plurality of openings at a predefined location. It is the predefined location on the one or more energy storage units at which the heat suppressing substance is directed and where the undesirable gas and smoke is expelled from the one or more energy storage units. This ensures that the heat suppressing substance neutralizes the source of the heat which may otherwise lead to flames.

[00032] As per one embodiment of the invention, in the energy storage system, the plurality of openings in the second portion is being configured to allow the discharge of the heat suppressing substance.

[00033] In yet another embodiment of the invention, a vehicle with an energy storage system having a thermal management system is disclosed. The vehicle comprises a frame assembly which is configured to provide a skeletal support to the vehicle. The frame assembly is also configured to mount the energy storage system. The energy storage system is configured to supply power to a plurality of components of the vehicle. The energy storage system comprises one or more energy storage units. In one aspect of the invention, the one or more energy storage units can include a main energy storage unit for powering one set of components of the vehicle requiring higher power such as a driving motor, a secondary energy storage unit for another set of the components such as electricals and electronics, and an auxiliary energy storage unit for other minor components. The energy storage system comprises the thermal management system which further comprises at least one storage member which is being configured to store a heat suppressing substance; one or more passages being configured to connect the at least one storage member to the one or more energy storage units. The one or more passages are configured to supply the heat suppressing substance from the at least one storage member to the one or more energy storage units to suppress a heat generated in the

one or more energy storage units. The thermal management system also comprises a control member which is configured to enable the at least one storage member to supply the heat suppressing substance to the one or more energy storage units upon a detection of one or more predefined conditions of the one or more energy storage units.

[00034] In yet another embodiment of the invention, a novel and inventive method of thermal management in an energy storage system is provided. The energy storage system includes one or more energy storage units. The method comprises, as a first step, monitoring one or more predefined conditions of the one or more energy storage units. Further, in second step, upon detection by a control member of the one or more predefined conditions of the one or more energy storage units being more than a predefined value, and the method involves supplying the heat suppressing substance from the at least one storage member to the one or more energy storage units through one or more passages.

[00035] As per one embodiment of the invention, in the of thermal management system, the step of discharging heat from an energy storage system, the method involves the discharging the heat suppressing substance from the one or more energy storage units through a plurality of openings in a second portion towards one or more collection units. The collection of the discharged heat suppressing substance by the one or more collection units. Further, transmitting the discharged heat suppressing substance from the one or more collection units back to at least one storage member through the one or more passages.

[00036] The embodiments of the present invention will now be described in detail with reference to an embodiment in a thermal management system along with the accompanying drawings. However, the disclosed invention is not limited to the present embodiments.

[00037] The embodiments shown in **Figure 1** illustrates a side perspective view of a thermal management system 100 for an energy storage system 200 of a vehicle (not shown) in one embodiment of the invention. The vehicle may be an electric vehicle or a hybrid vehicle or an internal combustion engine driven vehicle. The vehicle comprises of a frame assembly 300 which is configured to provide a skeletal

support to the vehicle. The frame assembly 300 mounts the energy storage system 200 that is configured to supply power to a plurality of components of the vehicle. The energy storage system 200 comprises a one or more energy storage units 201. The one or more energy storage units 201 can comprises one or more main energy storage unit, one or more secondary energy storage unit and one or more auxiliary energy storage unit 201A (as shown in Figure 2). The one or more main energy storage units 201 can be configured to power a prime mover of the vehicle which is capable of propelling the vehicle. The secondary battery unit can be configured to supply power to other electrical components such as control systems, lighting system, stereo system, horn, etc. The auxiliary energy storage unit 201A can be configured to power other minor electrical components of the vehicle for dedicated purposes. The thermal management system 100 can be detachably attached to the frame assembly 300 in this embodiment.

[00038] **Figure 1** is also reflecting one of the energy storage units 201 which is disposed on the foot rest of the vehicle while two energy storage units 201 are disposed below the rider and pillion seat in one or collection units 202 (shown in Figure 2). All the three energy storage units 201, are only connected by one or more passages 102 and are not electrically connected. Further, the auxiliary energy storage unit 201A being a 12V lead battery is disposed at the rear end of the vehicle above the rear fender and near the pillion handle of the vehicle. Furthermore, an at least one pumping member 104 (as shown in Figure 4) is powered through a secondary source to secure the functioning of the thermal management system 100 in the event of thermal runaway in the one or more energy storage units 201. It is to be noted that the thermal management system 100 is not confined to the energy storage system 200 of the type of vehicle shown herein. The same thermal management system 100 can be deployed on the vehicle belonging to a group consisting of 2-wheeled, 3-wheeled, 4-wheeled and other multi-wheeled vehicles. Further, the thermal management system 100 can also cater to non-vehicular applications other energy storage applications, power backups, electronic applications with wireless mode. The thermal management system 100 will now be described in more detail.

[00039] **Figure 2** and **Figure 3** have been taken together for discussion. The embodiments of **Figure 2** and **Figure 3** exemplarily illustrate the energy storage system 200 including the thermal management system 100. The one or more storage units 201 of the energy storage system 200 comprises a first portion 201f and a second portion 201s. Further, the first portion 201f of the energy storage system 200 is placed opposite to the second portion 201s of the energy storage system 200. The one or more energy storage units 201 can include various types of batteries or battery packs known in the art for example, Li-ion batteries, Nickel based batteries, lead acetate batteries etc. The one or more energy storage units 201 can also be configured as plurality of energy cells arranged together in a battery casing, such as in the case of a Li-ion batteries. The first portion 201f is being configured to serve as an entry point for the heat suppressing substance into the one or more energy storage units 201. The second portion 201s comprises an exit point for the heat suppressing substance. Both the first portion 201f and the second portion 201s comprise a plurality of openings which are configured to vent undesirable gases and smoke being generated from the one or more energy storage units 201. In one aspect of the invention, outer casing of the one or more energy storage units 201 can be configured to include predefined internal passages for venting the undesirable gases and heat during regular operation of the one or more energy storage units 201 through the same plurality of openings in the second portion 201s. These internal passages can be configured in such a manner that they pass through critical components of the one or more energy storage units 201 which are susceptible for heat or fire generation in case of a thermal runaway. In one aspect, the first portion 201f can be a top portion of the one or more energy storage units 201 and the second portion 201s can be a bottom portion of the one or more energy storage unit 201. In case the one or more energy storage units 201 is installed horizontally, the first portion 201f and the second portion 201s can be adjusted accordingly to ensure smooth flow of heat suppressing substance from the first portion 201f to the second portion 201s. The thermal management system 100 for the energy storage system 200 comprises of at least one storage member 101 which is configured to store the heat suppressing substance (not shown). The at least one storage member 101 is a

storage structure that comprises at least one inlet (not shown) and at least one outlet (not shown) with their respective caps or lids for storing the heat suppressing substance. The lid/cap for the at least one inlet can be used to fill-up or top-up heat suppressing substance in the at least one storage member 101. The at least one outlet

5 of the at least one storage member 101 is connected to the one or more passages 102 for enabling supply of heat suppressing substance upon detection of the predefined conditions. The one or more passages 102 are configured to connect the at least one storage member 101 to the one or more energy storage units 201. In one aspect of the invention, the one or more passages 102 are configured to supply the

10 heat suppressing substance to the first portion 201f of the one or more energy storage units 201 from where it travels across the predefined internal passages inside the one or more energy storage units 201 and is discharged through the second portion 201s. The one or more passages 102 are also configured to reroute the discharged heat suppressing substance from the second portion 201s back to the

15 at least one storage member 101. Thus, the heat suppressing substance is reintroduced in the at least one storage member 101 through the at least one inlet passage through the one or more passages 102. Alternatively, instead of directly connecting the second portion 201s to the at least one storage member 101, the heat suppressing substance can be discharged from the second portion 201s towards one

20 or more collection units 202 after suppressing the heat inside the one or more energy storage units 201. The one or more collection units 202 are being disposed below the second portion 201s to receive the heat suppressing substance. The one or more passages 102 can then be connected between the one or more collection units 202 and the at least one storage member 101 to reroute the heat suppressing substance

25 to the at least one storage member 101. The energy storage system 200 comprises a control member (not shown) that enables supply of the heat suppressing substance from the at least one storage member 101 to the one or more energy storage units 201 upon a detection of one or more predefined conditions of the one or more energy storage units 201. A plurality of sensors is being disposed in the one or more

30 storage units 201. The plurality of sensors is being configured to monitor the one or more predefined conditions of the one or more energy storage units 201. The

predefined conditions of the one or more energy storage units 201 can comprise a predefined level of temperature, pressure, etc. that is indicative of a thermal runaway or a situation where the one or more energy storage unit 201 likely to catch fire. Accordingly, known sensors in the art can be installed for continually or
5 periodically measuring the temperature or pressure inside the one or more energy storage units 201. The sensors are controlled and monitored through a control member (not shown). The control member can be an independent microcontroller for the thermal management system 100 or the control member can be integrated with a battery management system (BMS) of the energy storage system 200.
10 Alternatively, in case the thermal management system 100 is installed for the energy storage system 200 of a vehicle (not shown), the control member can also be integrated with the vehicle control systems. A skilled person will appreciate that threshold levels for the one or more predefined conditions can be different for different applications and battery types. The present invention is configured to
15 deploy the heat suppressing substance upon detection of a temperature above 60 degrees Celsius. Thus, in case of a thermal runaway or any sudden heat generation in one or more energy storage units 201, it will naturally give rise to the temperature at the very least. In one embodiment, when the sensors detect a temperature above 60 degrees Celsius, the control member shall enable a solenoid valve (not shown)
20 of the at least one storage member 101 to release the heat suppressing substance which will travel from the at least one storage member 101 to the one or more energy storage units 201 through the one or more passages 102. The solenoid valve can be installed near the at least one outlet of the at least one storage member 101 to enable egress of the heat suppressing substance and stop the flow when a
25 monitored level of the one or more predefined conditions returns to below the predefined levels. The heat suppressing substance is directed towards the first portion 201f of the one or more energy storage units 201. In one aspect, the heat suppressing substance can enter through the plurality of openings in the first portion 201f and travel in the predefined locations for example pre-existing internal
30 passages already present within the energy storage device. As already explained, the pre-existing internal passages inside the one or more energy storage units 201

are meant for degassing mechanism for relieving pressure built up in the one or more energy storage units 201. Thus, in this one aspect of the invention, the thermal management system 100, in the form of an external hydrant assembly can be functionally integrated with the pre-existing degassing mechanism in the energy storage devices 201. As already explained, the pre-existing degassing mechanism in the energy storage device involves passages that travel through critical portions that are likely to be the source of excessive heat such as fire, etc. Therefore, the above embodiment, ensures that the heat suppressing substance, when supplied from the at least one storage member 101, directly reaches the point of probable cause of excessive heat generation in the one or more energy storage units 201. Further, the heat suppressing substance is allowed to traverse through the first portion 201f and the second portion 201s of the one or more energy storage units 201. This way the invention is able to achieve external heat/fire prevention mechanism in combination with internal cooling mechanism without altering the design or adding new components for the pre-existing one or more energy storage units 201. Also, the same heat suppressing substance is circulated through the one or more passages 102 that cools the internal components as well as the first portion 201f and the second portion 201s of the one or more energy storage units 201 while preventing fire propagation.

[00040] The embodiment in **Figure 4** exemplarily illustrates the thermal management system 100 in more detail. The thermal management system 100 comprises the at least one storage member 101 to store the heat suppressing substance (not shown). The heat suppressing substance belongs to a group consisting of coolants, hydrants, suppressants, fire hydrant materials, heat transfer fluids, nanofluids or the like. The at least one storage member 101 is disposed at a higher elevation from ground than the one or more storage units 201 (as shown in Fig. 2). In one of the embodiments of the present application, the vehicle may comprise a plurality of storage members 101 as per the need or type of the vehicle or the category of the vehicle. This ensures that the heat suppressing substance from the at least one storage member 101 can be easily supplied to the one or more energy storage units 201 using gravitational pull. The at least one storage member 101 is

configured to have the solenoid valve (not shown). The control member is communicatively and functionally coupled with the sensors and the solenoid valve. The solenoid valve is responsible for controlling the flow of the heat suppressing substance thereby allowing, stopping and regulating the flow of heat suppressing substance based on the predefined levels of the one or more predefined conditions such as temperature and pressure within the one or more energy storage units 201. The solenoid valve can be selected from conventionally known types of configuration and sizes depending on the size of the at least one storage member 101 and the amount of the heat suppressing substance.

[00041] When the control member (not shown) through the plurality of sensors detects the one or more predefined conditions of the one or more energy storage units 201, the solenoid valve is actuated thereby opening the at least one storage member 101 allowing the thermal management system 100 to supply the heat suppressing substance to the one or more energy storage units 201. The one or more passages 102 can include one or more of ducts, pipes, tubes, integrated passages and hoses. However, a skilled person in the art would appreciate that the one or more passages 102 are not limited to the above types of passages. The one or more passages 102 include one or more inlet passages 102i and one or more outlet passages 102o. The one or more inlet passages 102i connect the at least one storage member 101 to the first portion 201f (shown in Fig. 3) of the one or more energy storage units 201. The one or more outlet passages 102o connect the one or more energy storage units 201 back to the at least one storage member 101 for re-routing the discharged heat suppressing substance. As already described, in an alternative embodiment, after cooling the one or more energy storage units 201, the heat suppressing substance can be discharged into one or more collection unit 202 placed below the second portion 201s of the one or more energy storage units 201. In this aspect, the outlet passage 102o can be connected from the one or more collection units 202 to the at least one storage member 101. The outlet passage 102o can also be part of the pre-existing internal de-gassing mechanisms provided in the predefined locations of the one or more energy storage units 201. Further, the entry point in the first portion 201f of the one or energy storage units 201 can be

configured in such a manner that it merges with the predefined locations like pre-existing internal de-gassing mechanisms in the one or energy storage units 201. The pre-existing internal degassing mechanism can be in the form of pre-existing internal passages designed so as to ensure release of undesirable gases in case of excessive heat generation in the one or more energy storage units 201. This merging of the thermal management system 100 with pre-existing internal degassing mechanisms or heat dissipation system ensures that the heat suppressing substance from the at least one storage member 101 reaches the exact region within the one or more energy storage units 201 which are likely to be the sources of the excessive heat generation leading to undesirable gases. This also contributes to the effectiveness and speed with which the thermal management system is able to contain the spread of excessive heat and avoid and/or contain the fire situation if any. Thus, the one or more outlet passages 102o is configured to supply the heat suppressing substance from the one or more collection units 202 back to the at least one storage member 101. In another aspect, a first distribution member 103f and a second distribution member 103s are placed between the one or more inlet passages 102i and the one or more outlet passages 102o respectively. Both the first distribution member 103f and the second distribution member 103s are the type of junctions that act as temporary storage medium for storing the heat suppressing substance in its intermediate stage before or after supplying of the heat suppressing substance to the one or more energy storage units 201, respectively. The first distribution member 103f enables supplying the heat suppressing substance from the at least one storage member 101 to more than the one or more energy storage units 201 by distributing accordingly the volume of the heat suppressing substance. The second distribution member 103s receives the heat suppressing substance from more than the one or more outlet passages 102o which may be receiving the discharged heat suppressing substance from more than the one collection units 202 or more than the one or more energy storage units 201 directly. This heat suppressing substance is further pumped by the at least one pumping member 104 (as shown in Figure 4) which is an electric motor pump. The electric pump is powered by the auxiliary energy storage unit 201A to supply the discharged heat

suppressing substance back to the at least one storage member 101. The control member is configured to control an operation of the electric motor pump to pump the heat suppressing substance from the one or more collection units 202 back to the at least one storage member 101 upon detection of the one or more predefined conditions of the one or more energy storage units 201.

[00042] **Figure 5** illustrates a method 500 of thermal management of an energy storage system 200. The method 500 comprises firstly, the step of monitoring 501 one or more predefined conditions of the one or more energy storage units 201. Secondly, the method involves detecting 502 by a control member the one or more predefined conditions of the one or more energy storage units 201 being more than a predefined level. Thirdly, supplying 503 a heat suppressing substance from the at least one storage member 101 to the one or more energy storage units 201 through one or more passages 102. The one or more predefined conditions can be a predefined level of temperature and/or a pressure in the one or more energy storage units 201. The predefined level is to be 60 degrees celsius in the one or more energy storage units 201 upon reaching which the control member is configured to actuate the thermal management system 100 to supply the heat suppressing substance to the one or more energy storage units 201. The method 500 also comprises, discharging 504 the heat suppressing substance through a plurality of openings in a second portion 201s of the one or more energy storage units 201 towards one or more collection units 202. Thereafter, discharged heat suppressing substance is collected 505 by the one or more collection units 202. Further, the method involves, transmitting 506 the collected heat suppressing substance from the one or more collection units 202 back to the at least one storage member 101 through the one or more passages 102 using one or more pumping member 104. In one aspect of the invention, this supplying 506 step can be executed using the at least one pumping member 104 as explained already in previous figures.

[00043] In one of the embodiments of the present application the energy storage system 200 comprises a control member (not shown) that enables supply of the heat suppressing substance from the at least one storage member 101 to the one or more energy storage units 201 upon a detection of one or more predefined conditions of

the one or more energy storage units 201. A plurality of sensors is being disposed in the one or more storage units 201. The plurality of sensors is being configured to monitor the one or more predefined conditions of the one or more energy storage units 201. The predefined conditions of the one or more energy storage units 201 can include a predefined level of temperature, pressure, etc. that is indicative of a thermal runaway or a situation where it is likely to catch fire. Accordingly, known sensors in the art can be installed for continually or periodically measuring the temperature or pressure inside the one or more energy storage units 201. The plurality of sensors is controlled and monitored through a control member (not shown). The control member can be an independent microcontroller for the thermal management system 100 or the control member can be integrated with a battery management system (BMS) of the energy storage system 200.

[00044] In view of the above embodiments, the present thermal management system 100 and the method 500 is enabled through various mechanisms to ensure a safe, effective and quick heat suppressing function. The system and method described herein above is controlled by the control member so as to execute a quick release of the heat suppressing substance from the at least one storage member 101 thereby ensuring that the source of excessive and sudden heat generation is neutralized without causing further damage or risk of serious injury. This is achieved by minimal number of additional components i.e., the at least one storage member 101 and the one or more passages 102 as controlled by the control member. This ensures that the weight and cost of the assembly of the thermal management 100 system remains minimal. In case of vehicles, existing storage members storing hydrants like water or coolant tanks can also be integrated with the above thermal management system 100 further eliminating requirements of additional parts for implementing the novel and inventive features. Thus, the configuration ensures cost effective solution for a serious problem without increasing complexity of the existing systems and without altering the existing designs of the one or more energy storage units 201 like batteries. The present invention also ensures that the thermal management system 100 is outside the one or more energy storage units 201 is securely and effectively couple or integrated with the pre-existing internal

degassing mechanisms in the one or more energy storage units 201. Compared to conventionally known cooling mechanisms using coolant circulation systems or immersion types systems, the proposed invention not only works in conjunction with pre-existing internal heat suppressing mechanisms or substances through
5 internal portions of the energy storage units 201 during normal working conditions, but also in case of excessive heat and pressure generation to mitigate fire hazards through internal as well as external mechanisms. The actuation of the thermal management system 100 based on detection of one or more predefined conditions, which in one preferred embodiment is detected and managed by the control
10 member, ensures that the thermal management kicks in quickly without delay and without allowing the excessive heat to transfer to neighboring parts of the one or more energy storage units 201.

[00045] The embodiments of this invention are not limited to vehicle with a thermal management system for its energy storage system and can cover any type of energy
15 storage system involving the thermal management system. For example, as used in this specification and the appended claims, the singular forms “a,” “an” and ““they”” can include plural referents unless the content clearly indicates otherwise. Further, when introducing elements/components/etc. of the assembly/system described and/or illustrated herein, the articles “a”, “an”, “the”, and “said” are
20 intended to mean that there is one or more of the element(s)/component(s)/etc. The terms “comprising”, “including”, and “having” are intended to be inclusive and mean that there may be additional element(s)/component(s)/etc. other than the listed element(s)/component(s)/etc.

[00046] This written description uses examples to provide details on the disclosure,
25 including the best mode, and also to enable any person skilled in the art to practice the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have
30 structural elements that do not differ from the literal language of the claims, or if

they include equivalent structural elements with insubstantial differences from the literal language of the claims.

[00047] It is to be understood that the aspects of the embodiments are not necessarily limited to the features described herein. Many modifications and
5 variations of the present subject matter are possible in the light of above disclosure.

List of Reference numerals:

100	Thermal management system
101	At least one storage member
102	One or more passages
102i	One or more inlet passages
102o	One or more outlet passages
103f	First distribution member
103s	Second distribution member
104	At least one pumping member
200	Energy storage system
201	One or more energy storage units
201A	Auxiliary energy storage unit
201f	First portion of the energy storage unit
201s	Second portion of the energy storage unit
202	One or more collection units
300	Frame assembly

We Claim:

1. A thermal management system (100) for an energy storage system (200),
the energy storage system (200) comprising one or more energy storage
units (201), the thermal management system (100) comprising:
5 at least one storage member (101), the at least one storage member
(101) being configured to store a heat suppressing substance;
 one or more passages (102), the one or more passages (102) being
configured to
 connect the at least one storage member (101) to the one or
10 more energy storage units (201), and
 supply the heat suppressing substance from the at least one
storage member (101) to the one or more energy storage units (201);
 and
 a control member, the control member being configured to enable
15 supply of the heat suppressing substance from the at least one storage
member (101) to the one or more energy storage units (201) to suppress heat
generated in the one or more energy storage units (201) upon a detection of
one or more predefined conditions.
2. The thermal management system (100) as claimed in claim 1, wherein the
20 one or more predefined conditions being a predefined level of at least one
of a temperature and a pressure in the one or more energy storage units
(201).
3. The thermal management system (100) as claimed in claim 1, wherein the
25 one or more storage units (201) being configured to have a first portion
(201f) and a second portion (201s), and wherein at least one of the first
portion (201f) and the second portion (201s) comprising a plurality of
openings, wherein the plurality of openings being configured to vent out
undesirable gas at high temperature and smoke generated inside the one or
more energy storage units (201).

4. The thermal management system (100) as claimed in claim 1, wherein the one or more passages (102) comprises one or more inlet passages (102i) and one or more outlet passages (102o).
5. The thermal management system (100) as claimed in claim 4, wherein the
5 at least one storage member (101) being disposed at a higher elevation from ground than the one or more energy storage units (201),
the one or more inlet passages (102i) of the one or more passages (102) being connected to the first portion (201f) of the one or more energy storage units (201), thereby the first portion (201f) being configured to serve
10 as an entry point for the heat suppressing substance into the one or more energy storage units (201),
the one or more outlet passages (102o) of the one or more passages (102) being connected to the second portion (201s) of the one or more energy storage units (201) to allow a discharge of the heat suppressing
15 substance towards one or more collection units (202) after suppressing the heat inside the one or more energy storage units (201), and
the one or more collection units (202) being disposed below the second portion (201s) to receive the heat suppressing substance,
and
20 the one or more outlet passages (102o) being configured to supply the heat suppressing substance from the one or more collection units (202) back to the at least one storage member (101).
6. The thermal management system (100) as claimed in claim 1, wherein the
25 at least one storage member (101) being configured to comprise a solenoid valve, the solenoid valve being configured to be actuated by the control member upon the detection of the one or more predefined conditions of the one or more energy storage units (201), thereby allowing the thermal management system (100) to supply the heat suppressing substance to the one or more energy storage units (201).

7. The thermal management system (100) as claimed in 5, wherein the thermal management system (100) comprises more than the one energy storage units (201),

5 the one or more inlet passages (102i) being configured to supply the heat suppressing substance from the at least one storage member (101) to the one or more energy storage units (201) *via* a first distribution member (103f); and

10 the one or more outlet passages (102o) connecting the one or more collection units (202) to the at least one storage member (101) via at least one pumping member (104) and a second distribution member (103s),

wherein the at least one pumping member (104) being configured to pump the heat suppressing substance from the second distribution member (103s) to the at least one storage member (101).

- 15 8. The thermal management system (100) as claimed in claim 7, wherein the at least one pumping member (104) being powered by an auxiliary energy storage unit (201A) and the control member being configured to control an operation of the pumping member (104) to pump the heat suppressing substance from the one or more collection units (202) back to the at least one storage member (101) upon detection of the one or more predefined conditions of the one or more energy storage units (201).

- 20 9. An energy storage system (200) comprising:

one or more energy storage units (201), the one or more energy storage units (201) being configured to supply an energy to one or more loads;

25 a thermal management system (100), the thermal management system (100) comprising:

at least one storage member (101), the at least one storage member (101) being configured to store a heat suppressing substance;

one or more passages (102), the one or more passages (102) being configured to connect the at least one storage member (101) to the one or more energy storage units (201), and

5 the one or more passages (102) being configured to supply the heat suppressing substance from the at least one storage member (101) to the one or more energy storage units (201) to suppress a heat generated in the one or more energy storage units (201); and

10 a control member, the control member being configured to enable supply of the heat suppressing substance from the at least one storage member (101) to the one or more energy storage units (201) upon a detection of one or more predefined conditions of the one or more energy storage units (201).

15 **10.** The energy storage system (200) as claimed in claim 9, wherein a plurality of sensors being disposed in the one or more energy storage units (201), the plurality of sensors being configured to monitor the one or more predefined conditions of the one or more energy storage units (201), the one or more predefined conditions being at least one of predefined levels of a temperature and a pressure inside the one or more energy storage units (201).

20 **11.** The energy storage system (200) as claimed in claim 9, wherein the thermal management system (100) being detachably attached to a frame assembly (300), wherein the frame assembly (300) being configured to mount the one or more energy storage units (201) and at least one storage member (101).

25 **12.** The energy storage system (200) as claimed in claim 9, wherein the one or more energy storage units (201) comprises a first portion (201f) and a second portion (201s), wherein the first portion (201f) and the second portion (201s) comprise a plurality of openings, and wherein the plurality of openings being configured to vent undesirable gases and smoke being generated from the one or more energy storage units (201).

30

5 **13.** The energy storage system (200) as claimed in claim 12, wherein the at least one storage member (101) being connected to the first portion (201f) of the one or more energy storage unit (201) *via* the one or more passages (102) such that the heat suppressing substance being supplied to the first portion (201f) through the plurality of openings at a predefined location, wherein the predefined location being a location on the one or more energy storage units (201) from where the undesirable gas and smoke being expelled from within the one or more energy storage unit (201), and the plurality of openings in the second portion (201s) being configured to allow the discharge of the heat suppressing substance.

10 **14.** A vehicle comprising:
 a frame assembly (300), the frame assembly (300) being configured to provide a skeletal support to the vehicle;
 the energy storage system (200), the energy storage system (200)
15 being configured to be mounted on the frame assembly (300), and the energy storage system (200) being configured to supply power to a plurality of components of the vehicle, the energy storage system (200) comprising:
 one or more energy storage units (201); and
 a thermal management system (100), the thermal management
20 system (100) comprising:
 at least one storage member (101), the at least one storage member (101) being configured to store a heat suppressing substance;
 one or more passages (102), the one or more passages (102)
25 being configured to connect the at least one storage member (101) to the one or more energy storage units (201) and the one or more passages (102) being configured to supply the heat suppressing substance from the at least one storage member (101) to the one or more energy storage units (201) to suppress a heat generated in the
30 one or more energy storage units (201); and

5 a control member, the control member being configured to enable the at least one storage member (101) to supply the heat suppressing substance to the one or more energy storage units (201) upon a detection of one or more predefined conditions of the one or more energy storage units (201).

15. A method (500) of thermal management in an energy storage system (200) the energy storage system (200) comprising one or more energy storage units (201), the method (500) comprising steps of:

10 monitoring (501) one or more predefined conditions of the one or more energy storage units (201);

detecting (502) by a control member the one or more predefined conditions of the one or more energy storage units (201) being more than a predefined level; and

15 supplying (503) a heat suppressing substance from at least one storage member (101) to the one or more energy storage units (201) through one or more passages (102).

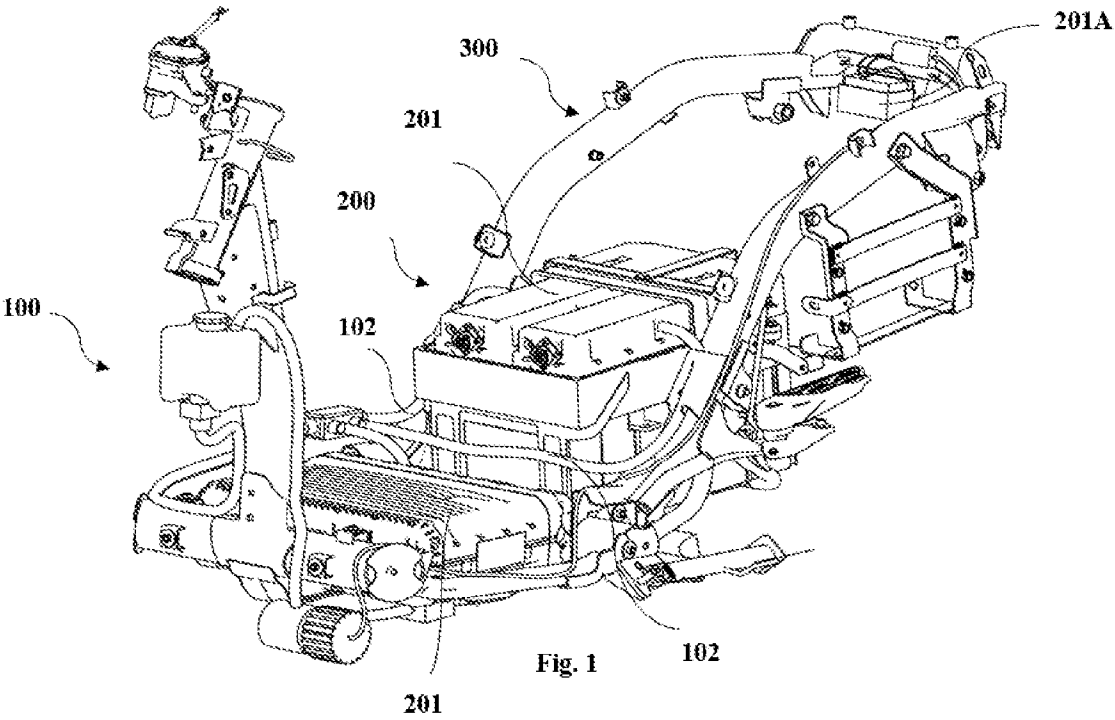
16. The method (500) as claimed in claim 15, wherein the method (500) of the thermal management comprising:

20 discharging (504) the heat suppressing substance through a plurality of openings in a second portion (201s) towards one or more collection units (202) after the supply (503) of the heat suppressing substance to the one or more energy storage units (201);

25 collecting (505) the heat suppressing substance discharged from the one or more energy storage units (201) by the one or more collection units (202); and

transmitting (506) the collected heat suppressing substance from the one or more collection units (202) back to the at least one storage member (101) through the one or more passages (102) using at least one pumping member (104).

17. The method (500) as claimed in claim 15, wherein the one or more predefined conditions being a predefined level of at least one of a temperature and a pressure in the one or more energy storage units (201).



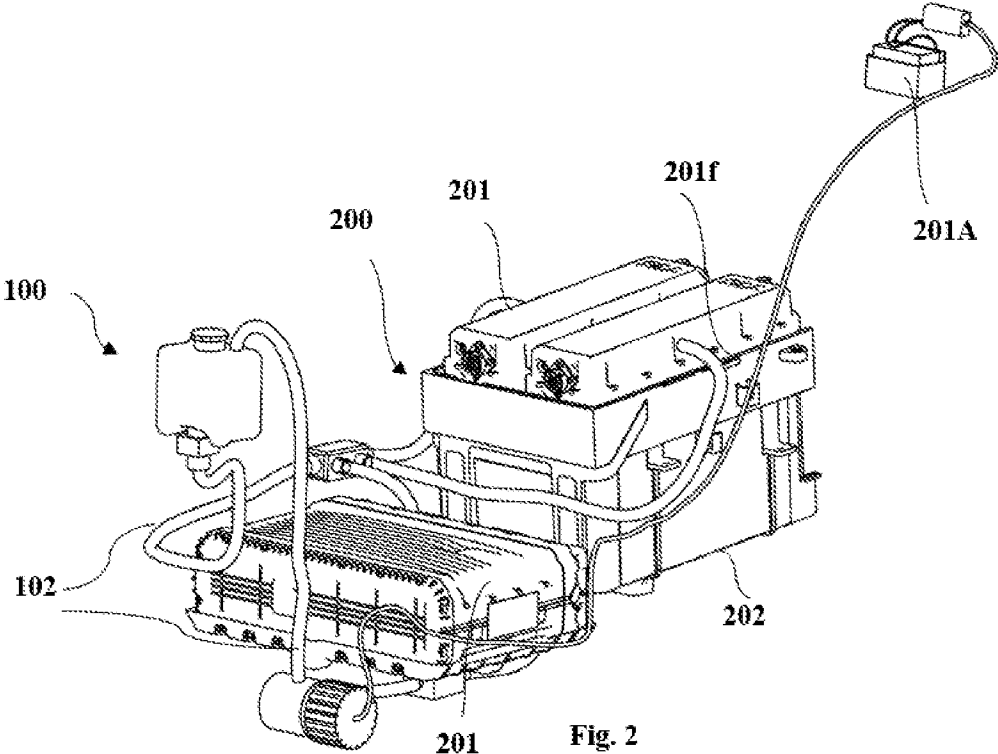
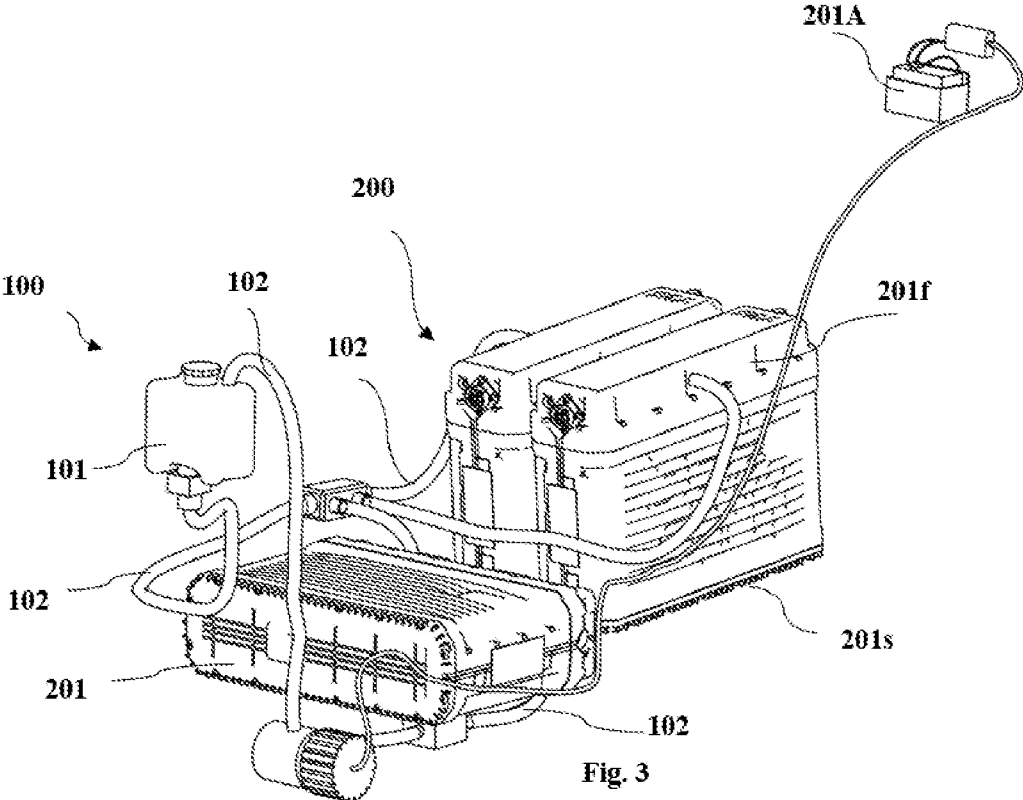


Fig. 2



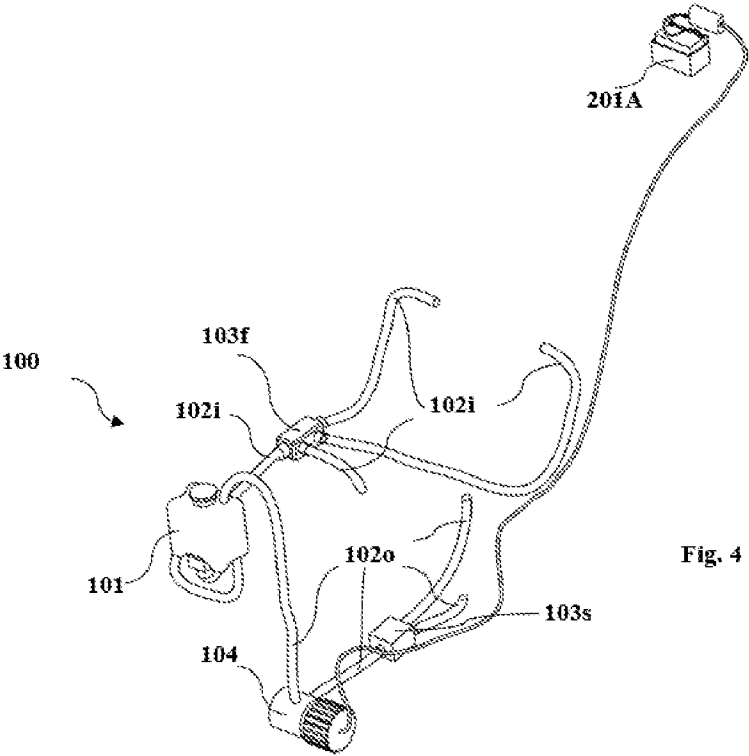
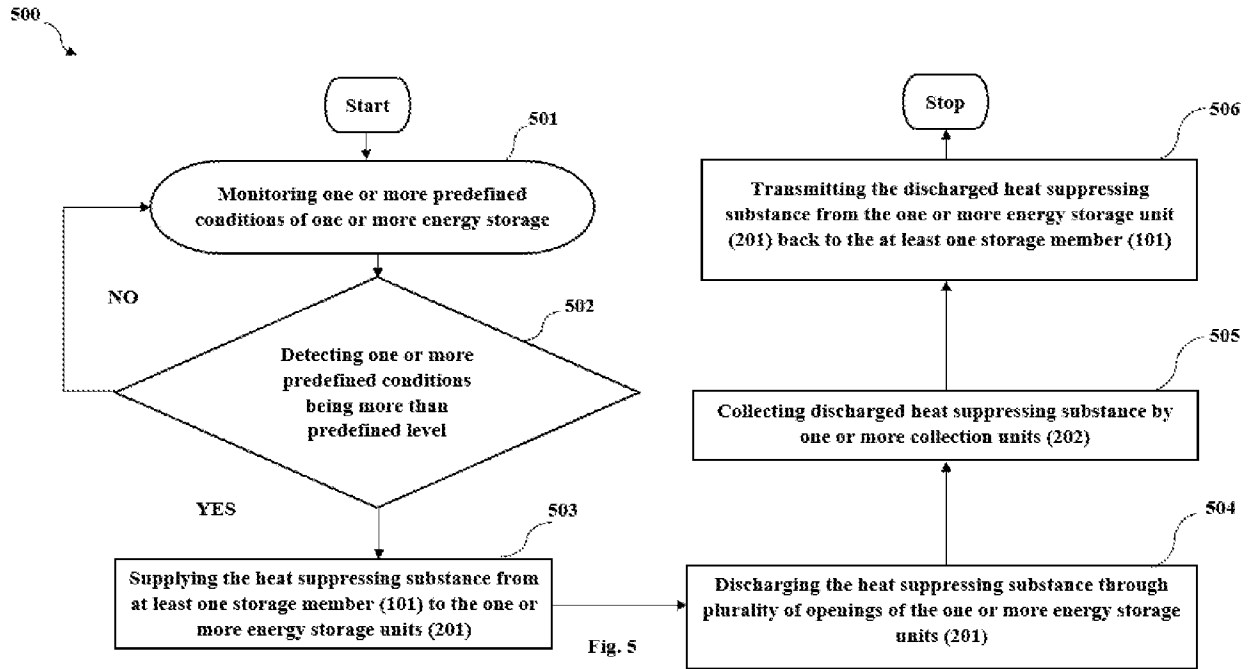


Fig. 4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2024/050546

A. CLASSIFICATION OF SUBJECT MATTER
H01M10/613, H01M10/6567 Version=2024.01

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*

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

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

PatSeer, IPO Internal Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US11670812B1 (SHENZHEN KUBO ENERGY TECH CO LTD [CN]) 06 June 2023 (06.06.2023) Col 1, Lines 40-60, Col 2, Lines 14-20, Col 3, Line 57-68-Col 4, Line 0-20 & Figs 1-4	1-17
A	CN111584242A (SHANGHAI AOWEI TECH DEVELOPMENT CO LTD) 25 Aug 2020 (25.08.2020) Para 0004-0030 & Figs 1-8 (English translation on espacenet)	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"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

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Date of the actual completion of the international search

06-09-2024

Date of mailing of the international search report

06-09-2024

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IN2024/050546

Citation	Pub.Date	Family	Pub.Date
US 11670812 B1	06-06-2023	CN 114267889 B	08-11-2022
CN 111584242 A	25-08-2020	WO 2021232970 A1	25-11-2021