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BATTERY PACK

Abstract

A battery pack to be installed in an electric mobile object includes a battery cell, and a cold storage member configured to cool the battery cell. The cold storage member includes a supporter that has a wall defining a space therein, a cold storage material that is disposed in the space and supported by the supporter, and a beam that bridges the wall. The supporter and the beam are made of a material that has a better thermal conductivity than the cold storage material.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] The present application is a continuation application of International Patent Application No. PCT/JP2023/040144 filed on Nov. 8, 2023, which designated the U.S. and claims the benefit of priority from Japanese Patent Application No. 2022-182748 filed on Nov. 15, 2022. The entire disclosures of all the above applications are incorporated herein by reference.

TECHNICAL FIELD
[0002] The disclosure in this specification relates to a battery pack installed in an electric mobile object.
BACKGROUND
[0003] A battery pack is installed in an electric mobile object.
SUMMARY
[0004] A battery pack of the present disclosure is a battery pack to be installed in an electric mobile object. The battery pack includes a battery cell, and a cold storage member configured to cool the battery cell. The cold storage member includes a supporter, a cold storage material, and a beam. The supporter has a wall defining a space therein. The cold storage material is disposed in the space and supported by the supporter. The beam bridges the wall. The supporter and the beam are made of a material that has a greater thermal conductivity than the cold storage material.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0005] FIG. **1** is a diagram showing a schematic configuration of an eVTOL.
[0006] FIG. **2** is a diagram showing a power profile.
[0007] FIG. **3** is a top view illustrating a schematic configuration of a battery pack according to a first embodiment.
[0008] FIG. **4** is a cross-sectional view taken along a line IV-IV in FIG. **3**.
[0009] FIG. **5** is a cross-sectional view showing a supporter and beams.
[0010] FIG. **6** is a side view of the supporter and the beams.
[0011] FIG. **7** is a graph showing the effect of a latent heat storage material.
[0012] FIG. **8** is a diagram showing an effect of the beams.
[0013] FIG. **9** is a graph showing the phase state of a cold storage material.
[0014] FIG. **10** is a diagram showing a modified example.
[0015] FIG. **11** is a diagram showing a modified example.
[0016] FIG. **12** is a diagram showing the arrangement of battery cells and a cold storage member in a battery pack according to a second embodiment.
[0017] FIG. **13** is a perspective view of a cold storage member in a battery pack according to a third embodiment.
[0018] FIG. **14** is a cross-sectional view of a modified example.
[0019] FIG. **15** is a graph showing the relationship between the beam pitch and the phase change time in a battery pack according to a fourth embodiment.

[0020] FIG. **16** is a diagram of a modified example.
[0021] FIG. **17** is a cross-sectional view of a battery pack according to a fifth embodiment.
[0022] FIG. **18** is a top view illustrating a schematic configuration of the battery pack according to a sixth embodiment.
[0023] FIG. **19** is a cross-sectional view showing a cold storage member according to the sixth embodiment.
[0024] FIG. **20** is a partially enlarged view of the cold storage member in FIG. **19**.
[0025] FIG. **21** is a cross-sectional perspective view of the cold storage member according to the sixth embodiment.
[0026] FIG. **22** is a diagram showing the cold storage member filled with a cold storage material.
[0027] FIG. **23** is a diagram of a modified example.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0028] To begin with, examples of relevant techniques will be described.

[0029] A battery pack is installed in an electric mobile object.

[0030] The battery pack includes a battery cell and a cold storage material. The cold storage material is disposed in contact with the battery cell. The cold storage material is a latent heat storage material that absorbs heat from the battery cell by utilizing a phase change from solid to liquid. However, the cold storage material has a low thermal conductivity. Thus, simply bringing the cold storage material into contact with the battery cell is insufficient to transfer heat to the inside of the cold storage material. In the viewpoints described above, or in not-mentioned another viewpoint, the battery pack needs further improvements.

[0031] It is an objective of the present disclosure to provide a battery pack that has a higher heat dissipation performance.

[0032] A battery pack of the present disclosure is a battery pack to be installed in an electric mobile object. The battery pack includes a battery cell, and a cold storage member configured to cool the battery cell. The cold storage member includes a supporter, a cold storage material, and a beam. The supporter has a wall defining a space therein. The cold storage material is disposed in the space and supported by the supporter. The beam bridges the wall. The supporter and the beam are made of a material that has a greater thermal conductivity than the cold storage material.

[0033] According to the disclosed battery pack, the beam that bridges the wall of the supporter has superior thermal conductivity to the cold storage material. Thus, heat generated by the battery cell can be effectively dissipated from the supporter through the beam. As a result, the battery pack with high heat dissipation performance can be provided.

[0034] The disclosed aspects in this specification adopt different technical solutions from each other in order to achieve their respective objectives. The objects, features, and advantageous effects disclosed in this description will become more apparent with reference to the following detailed description and accompanying drawings.

[0035] The following sections describe multiple embodiments based on the accompanying drawings. In each embodiment, corresponding components may be denoted by the same reference numerals, and redundant descriptions may be omitted. When describing only a part of a structure in each embodiment, other parts of the structure may be applied from the previously described embodiments. Additionally, not only the explicitly stated combinations of structures in the description of each embodiment but also partial combinations of structures from multiple embodiments can be made, provided that there are no particular issues with such combinations.

[0036] (First Embodiment) A battery pack of this embodiment is mounted on an electric mobile object. The electric mobile object can move by driving a rotating electric machine. Examples of the electric mobile object include a vehicle, a flying object, a ship, a construction machine, and an agricultural machine. The electric vehicle may be a battery electric vehicle (BEV), a hybrid electric vehicle (HEV), or a plug-in hybrid electric vehicle (PHEV). BEV is an abbreviation for Battery Electric Vehicle. HEV is an abbreviation for Hybrid Electric Vehicle. PHEV is an abbreviation for

Plug-in Hybrid Electric Vehicle.
[0037] Examples of the electric flying object include an electronic vertical take-off and landing aircraft (eVTOL), an electronic short distance take-off and landing aircraft (eSTOL), and a drone. The eVTOL is an abbreviation of an electronic vertical take-off and landing aircraft. The eSTOL is an abbreviation of an electronic short distance take-off and landing aircraft. The following describes the battery pack installed in an eVTOL as an example.
[0038] <eVTOL> FIG. **1** shows a schematic configuration of the eVTOL. As an example, the eVTOL **10** of this embodiment includes an aircraft body **11**, fixed wings **12**, rotary wings **13**, lift adjustment mechanisms **14**, batteries **15**, EPUs **16**, BMSs **17**, and an ECU **18**.
[0039] The aircraft body **11** is the fuselage of the aircraft. The aircraft body **11** has a shape that extends in the front-rear direction. The aircraft body **11** defines a passenger compartment for passengers and/or a luggage compartment for carrying luggage.
[0040] The fixed wings **12** are wings of the aircraft and connected to the aircraft body **11**. The fixed wings **12** provide the gliding lift. The gliding lift is the lift generated by the fixed wings **12**. As an example, the fixed wings **12** include a main wing **121** and a tailplane **122**. The main wing **121** extends left and right from near the center of the aircraft body **11** in the front-rear direction. The tailplane **122** extends left and right from the rear of the aircraft body **11**. The shape of the fixed wings **12** is not particularly limited. For example, swept-back wings, delta wings, straight wings may be used.
[0041] The multiple rotary wings **13** are provided on the aircraft. At least one of the rotary wings **13** may be provided on the fixed wings **12**. At least one of the rotary wings **13** may be provided on the aircraft body **11**. The number of the rotary wings **13** included in the eVTOL **10** is not particularly limited. As an example, the multiple rotary wings **13** are provided on the aircraft body **11** and the main wing **121**, respectively. The eVTOL **10** has six rotary wings **13**.
[0042] The rotary wings **13** each may be referred to as a rotor, a propeller, or a fan. The rotary wings **13** each have blades **131** and a shaft **132**. The blades **131** are attached to the shaft **132**. The blades **131** are vanes that rotate together with the shaft **132**. The multiple blades **131** extend radially about the axis of the shaft **132**. The shaft **132** is a rotation axis of the rotary wing **13** and is rotated by a motor of the EPU **16**.
[0043] The rotary wings **13** rotate to generate propulsive force. The propulsive force acts on the eVTOL **10** primarily as rotational lift during takeoff and landing of the eVTOL **10**. The rotary wings **13** primarily provide rotational lift during takeoff and landing. The rotational lift is a lift force generated by the rotation of the rotary wings **13**. During takeoff and landing, the rotary wings **13** may provide only rotational lift, or may provide both rotational lift and forward thrust. The rotary wings **13** provide rotational lift when the eVTOL **10** is hovering.
[0044] The propulsive force acts on the eVTOL **10** when the eVTOL **10** is cruising. The rotary wings **13** primarily provide thrust when the eVTOL is cruising. During cruise, the rotary wings **13** may provide thrust alone or may provide both lift and thrust.
[0045] The lift adjustment mechanisms **14** adjust the gliding lift of the fixed wings **12**. The lift adjustment mechanisms **14** increase or decrease the gliding lift generated by the fixed wings **12**. The lift adjustment mechanisms **14** adjust the gliding lift by, for example, adjusting at least one of the surface area, angle of attack (AOA), camber (i.e., curvature of airfoil), stall AOA, and wing velocity of the fixed wings **12**. AOA is an abbreviation for Angle Of Attack. As an example, the lift adjustment mechanisms **14** include tilt mechanisms **141** and flaps **142**.
[0046] The tilt mechanisms **141** are driven to adjust the tilt angle of the rotary wings **13**. Each of the tilt mechanisms **141**, together with a motor and an inverter that drive the tilt mechanism **141**, constitute a tilt adjustment device. The tilt adjustment device including the tilt mechanism **141** may be provided each for the rotary wings **13**. The tilt mechanisms **141** adjust the tilt angle of the rotary wings **13** by adjusting the relative inclination of the rotary wings **13** with respect to the aircraft.
[0047] During takeoff and landing, the tilt mechanisms **141** control the tilt angle so that the axis of

each of the rotary wings **13** approaches a position parallel to the vertical direction. As a result, the propulsive force generated by the rotation of the rotary wings **13** acts on the eVTOL **10** primarily as rotational lift. Therefore, the eVTOL **10** is capable of short or vertical takeoff and landing.

[0048] During cruising, the tilt mechanisms **141** adjust the tilt angle so that the axis of each of the rotary wings **13** approaches a position parallel to the horizontal direction. As a result, the propulsive force generated by the rotation of the rotary wings **13** acts on the eVTOL **10** mainly as thrust. Thus, the eVTOL **10** can move forward using forward thrust generated by the rotation of the rotary wings **13** while obtaining gliding lift from the fixed wings **12**. In addition, the gliding lift can be adjusted by changing the wing velocity with thrust.

[0049] Although an example in which the tilt mechanisms **141** are provided respectively for the rotary wings **13** has been shown, the present disclosure is not limited to this. For example, a common tilt mechanism may adjust the tilt angles of the multiple rotary wings **13** arranged side by side. The rotary wings **13** may be integrated with a part of a wing component, and the part of the wing component and the rotary wings **13** may be collectively displaced by a tilt mechanism.

[0050] The flaps **142** are movable wing pieces and provided on the fixed wing **12**. Each of the flaps **142**, together with a motor and an inverter that drive the flap **142**, constitute a flap adjustment device. The flaps **142** are sometimes referred to as high-lift devices. As an example, the multiple flaps **142** are provided on the trailing edge of the main wing **121**. Each of the multiple flaps **142** is provided with a motor and an inverter. The flaps **142** may be provided on the tailplane **122** in addition to the main wing **121**. The flaps **142** may be provided on the leading edge of the fixed wings **12**.

[0051] The flaps **142** adjusts the surface area and camber of the fixed wings **12**. For example, the gliding lift acting on the main wing **121** increases by adjusting the flaps **142** provided on the main wing **121** to a lower position. Additionally, the gliding lift can be further increased by moving the flaps **142** in a direction extending beyond the main wing **121**.

[0052] The lift adjustment mechanisms **14** are not limited to the tilt mechanisms **141** and the flaps **142** described above. The lift adjustment mechanisms **14** may include a tilt mechanism that adjusts the relative inclination of the fixed wings **12** with respect to the aircraft body **11**. In this case, the angle of attack of the fixed wings **12** can be adjusted. The lift adjustment mechanisms **14** may include another rotary wing for thrust that is provided separately from the rotary wing **13**. In this case, the wing velocity can be adjusted. Moreover, providing a rotary wing for thrust allows the rotary wing **13** to be used exclusively for lift (i.e., rotational lift).

[0053] The lift adjustment mechanism **14** may include a variable wing. The variable wing can adjust lift by changing the surface area, camber, and angle of incidence of the fixed wings **12**. The lift control mechanism **14** may include a high-lift device other than the flaps **142**, such as slats. The slats are provided on the leading edge of the main wing **121**. By moving the slats forward relative to the main wing **121**, a gap is defined between the slats and the main wing **121**, thereby delaying separation. Thus, lift can be increased up to a higher angle of attack without stalling. That is, the stall AOA can be delayed.

[0054] The batteries (BAT) **15** are rechargeable secondary batteries capable of storing direct current power. The batteries **15** supply power to the EPUs **16**, the ECU **18**, the tilt adjustment devices, and the flap adjustment devices. The batteries **15** also supply power to auxiliary equipment (not shown), such as an air conditioner. As an example, the eVTOL **10** of this embodiment includes multiple batteries **15**. The multiple batteries **15** may be connected to each other in series and/or parallel, or may be arranged independently without being connected to each other. The batteries **15** may be provided respectively for the EPUs **16** or may be provided redundantly for the EPUs **16**.

[0055] Each of the EPUs **16** includes a motor and an inverter, and rotationally drives the rotary wing **13** which applies propulsive force to the eVTOL **10**. The EPU is an abbreviation of an electric propulsion unit. As an example, the number of the EPUs **16** is the same as the number of the rotary wings **13**. In other words, the eVTOL **10** has six EPUs **16**. The EPUs **16** and the rotary wings **13** are connected in a one-to-one relationship. Alternatively, two or more rotary wings **13** may be connected to a single EPU **16** via a gear box.

[0056] The BMSs **17** monitor the state of the batteries **15**. The BMS is an abbreviation of a battery management system. For example, a single BMS **17** is provided for a single battery **15**. The BMSs **17** may predict or detect an abnormality of the batteries **15** by monitoring the state of each of the batteries **15**.

[0057] The ECU **18** controls the flight of the eVTOL **10**. ECU is an abbreviation of Electronic Control Unit. The ECU **18** performs control to fly the eVTOL **10** in a flight state according to operation by a pilot as an operator, remote operation by an operator, or control by a control system. The ECU **18** executes flight control based on the detection results of the BMS **17** and various sensors. The ECU **18** controls devices such as the motors of the EPUs **16**, the motors of the tilt adjustment devices, and the motors of the flap adjustment devices. The ECU **18** may control the auxiliary machinery.

[0058] <Power Profile> FIG. **2** shows a power profile from take-off to landing of the eVTOL **10**. It should be noted that the power profile of electric flying vehicles other than eVTOL is similar to that of eVTOL. A period K**1** is referred to as a take-off period, a take-off time, a departure period, a departure time, or the like. A period K**2** is referred to as a cruising period, a cruising time, or the like. A period K**3** is referred to as a landing period, a landing time, an arrival period, an arrival time, or the like. For illustrative purposes, the required power (i.e., output) during the periods K**1** and K**2** in FIG. **2** is substantially constant.

[0059] The eVTOL **10** moves up from a take-off point to a cruising start point during the period K**1**. The eVTOL **10** cruises at a predetermined altitude during the period K**2**. The eVTOL **10** moves down from an end point of the period K**2** to a landing point during the period P**3**. The movement of the eVTOL **10** mainly includes a horizontal direction component during the period P**2** and mainly includes a vertical direction component during the periods K**1** and K**3**. High output is required continuously for a predetermined time to drive the rotary wings **13** of the eVTOL **10** during the periods K**1** and K**3** during which the eVTOL **10** moves in the vertical direction.

[0060] This high output places a large load on the batteries **15** and EPUs **16**, which are driving devices for the rotary wings **13**. For example, the batteries **15** generate heat and their temperature rises temporarily.

[0061] <Battery Pack> FIG. **3** shows the schematic configuration of a battery pack. In FIG. **3**, a part of the housing is omitted in order to show battery cells housed in the housing. In FIG. **3**, illustration of some of the battery cells **30** are omitted. FIG. **4** shows the arrangement of the battery cells and a cold storage member. FIG. **4** is a cross-sectional view taken along a line IV-IV of FIG. **3**. FIG. **4** illustrates a simplified configuration of the battery cells. FIG. **5** shows the structure of the cold storage member of FIG. **4** without a cold storage material. That is, the structure based on a supporter and beams is shown. FIG. **6** is a side view showing the structure of the supporter and the beams.

[0062] In the following, the height direction, the longitudinal direction, and the width direction of each battery cell are indicated as the Z direction, the Y direction, and the X direction, respectively. The X direction, the Y direction, and the Z direction are orthogonal to each other.

[0063] As shown in FIGS. **3** and **4**, the battery pack **20** includes multiple battery cells **30**, cold storage members **40**, and a housing **50**. The battery pack **20** also includes bus bars, connectors, and fixing members (not shown).

[0064] Each battery cell **30** is a secondary battery that generates an electromotive voltage by a chemical reaction. The battery cell **30** may be a lithium-ion secondary battery, a nickel-hydrogen secondary battery, or an organic radical battery. The battery cell **30** may be a secondary battery in which the electrolyte is liquid, or a so-called all-solid-state battery in which the electrolyte is solid.

[0065] The battery cells **30** have a common structure. The number and arrangement of the battery cells **30** are not particularly limited. The multiple battery cells **30** may be connected in series, or may be connected in parallel and in series. As an example, the battery cells **30** in this embodiment are connected in series. The multiple battery cells **30** are arranged side by side in the X direction. The multiple battery cells **30** are stacked in the X direction with the cold storage members **40** interposed therebetween. The battery pack **20** may include multiple stacks of the battery cells **30**. An electrically connected structure of the multiple battery cells **30** is sometimes called a battery module. The multiple battery cells **30** included in a single battery pack **20**, that is, a battery module, corresponds to one of the batteries **15** described above.

[0066] Each battery cell **30** includes a power generating element and a battery case that accommodates the power generating element. The battery case is an outer casing for the battery cell **30**. The battery case may be formed of metal. The shape of the battery cell **30**, i.e., the battery case, is not particularly limited. The battery case may have a cylindrical shape, or a rectangular shape. As an example, the battery cell **30** of this embodiment has a rectangular shape, specifically, a thin and flat shape in the X direction.

[0067] The battery cell **30** has a top surface **30***a*, a bottom surface **30***b*, and four side surfaces **30***c*. The bottom surface **30***b* is opposite to the top surface **30***a* in the Z direction. The side surfaces **30***c* connect between the top surface **30***a* and the bottom surface **30***b*. Two of the side surfaces **30***c* are opposite to each other in the X direction. The other two of the side surfaces **30***c* are opposite to each other in the Y direction.

[0068] The multiple battery cells **30** are arranged side by side in the X direction. Each battery cell **30** has electrode terminals **31**P, **31**N protruding from the top surface **30***a*. The electrode terminal **31**P is electrically connected to the positive electrode of the battery cell **30**. The electrode terminal **31**P may be referred to as a positive electrode terminal or a P terminal. The electrode terminal **31**N is electrically connected to the negative electrode of the battery cell **30**. The N-terminal may be referred to as a negative electrode terminal or a N terminal. The electrode terminals may be referred to as current collecting tabs.

[0069] The multiple battery cells **30** are arranged such that the electrode terminals **31**P and the electrode terminals **31**N are positioned alternately in the X direction. Moreover, the battery cells **30** are arranged such that the positions of the top surfaces **30***a* in the Z-direction are substantially equal to each other. The relative positions of the multiple battery cells **30** are fixed by fixing members (not shown). The fixing member may be a case or a restraining member such as a band.

[0070] In the above-described arrangement, the electrode terminals **31**P, **31**N of adjacent battery cells **30** are electrically connected by a bus bar (not shown). In other words, the multiple battery cells **30** are connected in series by the bus bars.

[0071] Each cold storage member **40** includes a supporter **41**, a cold storage material **42**, and beams **43**. When the thickness of the cold storage member **40** is relatively thin compared to the battery cell **30**, the cold storage member **40** may be referred to as a cold storage sheet.

[0072] The supporter **41** supports the cold storage material **42**. The supporter **41** has a wall **411** and a space **412** defined by the wall **411** therein. The supporter **41** holds the cold storage material **42** in its storage space. The supporter **41** is formed of a material having superior thermal conductivity to the cold storage material **42**. The supporter **41** may be formed of a metal, a ceramic, or a resin containing fillers.

[0073] As an example, the supporter **41** in this embodiment is formed of a metal, specifically, an aluminum-based material. The supporter **41** has a thin box shape that is thin in the X direction. The supporter **41** includes facing walls **411***a* and **411***b* and side walls **411***c*. The facing walls **411***a* and **411***b* face each other in the X direction. The side walls **411***c* connect between the ends of the facing walls **411***a* and **411***b* and closes the space **412**.

[0074] The cold storage material **42** exhibits a cold storage effect. The cold storage material **42** cools the battery cell **30** by absorbing heat generated by the battery cell **30**. The cold storage material **42** may be a latent heat storage material for cooling. Instead of the latent heat storage material, water or cooling water to which LLC has been added may be used as the cold storage material **42**. LLC is an abbreviation for long life coolant. The cold storage material is sometimes called a heat storage material.

[0075] As an example, the cold storage material **42** in this embodiment is a latent heat storage material for cooling. The latent heat storage material is sometimes called PCM. PCM is an abbreviation for Phase Change Material. The phase of the latent heat storage material changes between solid and liquid. The latent heat storage material uses the latent heat of a substance. The latent heat storage material maintains the temperature of the battery cell **30** at a predetermined temperature or within a predetermined temperature range. The latent heat storage material may be anhydrous carbon compound, specifically a paraffin compound. Alternatively, the latent heat storage material may be hydrates. Hydrates may be hydrates of sodium acetate, sodium sulfate, sodium nitrate.

[0076] As an example, the cold storage material **42** in this embodiment is an anhydrous carbon compound, specifically a paraffin-based cold storage material. The phase transition temperature of the cold storage material **42** between the solid phase and the liquid phase is set within the range of 30° C. to 60° C. The cold storage material **42** (e.g., the paraffin-based cold storage material) has a higher density in the solid phase than in the liquid phase. Thus, when the cold storage material **42** changes from the solid phase to the liquid phase, the volume expands by about 10%. Therefore, the filling rate of the cold storage material **42** in the solid phase for the space **412** is adjusted such that the filling rate in the liquid phase is equal to or less than 100%, and close to 100%.

[0077] The beams **43** bridge the walls **411** of the supporter **41**. The beams **43** are in contact with the cold storage material **42**. The beams **43** may be referred to as bridging members. The beams **43**, like the supporter **41**, are formed of a material having superior thermal conductivity to the cold storage material **42**. The beams **43** may be formed of a metal, a ceramic, or a resin containing fillers. The beams **43** may be made of material same as that of the supporter **41**, or may be made of material different from that of the supporter **41**. The beams **43** may be seamlessly connected to and integrally formed with the supporter **41**, or may be connected to the supporter **41** by bonding. The beams **43** may bridge different parts of the walls **411**.

[0078] As an example, the beams **43** of the present embodiment bridge the two facing walls **411***a*, **411***b* as shown in FIGS. **4** and **5**. As shown in FIG. **6**, the multiple beams **43** extending in the Y direction are provided integrally with the supporter **41**. Each of the beams **43** has at least a part in contact with the cold storage material **42**. The beams **43** are provided at a predetermined pitch P**1** in the Z direction. The beams **43** divide the space **412**, that is, the cold storage material **42** disposed in the space **412**, into multiple sections. The beams **43** may be referred to as separators, or separation walls. The beams **43** are continuously connected to the supporter **41**. The beams **43** and the supporter **41** are integrally formed with each other by extrusion tubing using an aluminum-based material. Extrusion tubing is sometimes referred to as extrusion pipe processing.

[0079] As shown in FIG. **3**, the cold storage members **40** having the above-described structure are arranged alternately with the battery cells **30** in the X direction, which is the stacking direction. As shown in FIG. **4**, the facing wall **411***a* of the supporter **41** is in direct contact with one side surface **30***c* of the battery cell **30**. The facing wall **411***b* of the supporter **41** is in direct contact with one side surface **30***c* of another battery cell **30**. The cold storage member **40** is interposed between and held by the battery cells **30** in the X direction. The facing walls **411***a* and **411***b* may be in indirect contact with the battery cells **30**. For example, the facing walls **411***a* and **411***b* may be in indirect contact with the battery cells **30** through a thermal conductive member (not shown) such as a TIM. The TIM is an abbreviation for Thermal Interface Material. The cold storage member **40** may be adhesively fixed to the battery cells **30**.

[0080] FIG. **3** shows an example in which the battery cells **30** located at both ends in the stacking direction is in contact with the cold storage member **40** only on one side surface, specifically only on the inner side surface in the stacking direction. Instead of this, the cold storage members **40** may be disposed on the outer side surfaces of the battery cells **30** located at both ends in the stacking direction. In this case, only one of the facing walls **411***a* and **411***b* of the cold storage members **40** located at both ends in the stacking direction is in contact with the side surfaces **30***c* of the battery cells **30**.

[0081] The housing **50** houses the battery cells **30**. The housing **50** may be formed of a metal such as aluminum, or a resin material. The cold storage member **40** may be housed in the housing **50**, or at least a portion of the cold storage member **40** may be disposed outside the housing **50**. As an example, the housing **50** of the present embodiment is formed (e.g., die-cast formed) using an aluminum-based material. The housing **50** accommodates the battery cells **30** and the cold storage members **40**. The heat generated by the battery cells **30** is dissipated through the cold storage members **40** to, for example, the bottom wall of the housing **50**. The bottom wall is a wall of the housing **50** facing the bottom surfaces **30***b* of the battery cells **30**.

[0082] <Summary of First Embodiment> According to the present embodiment, the battery pack **20** includes the cold storage members **40**. Each cold storage member **40** includes the supporter **41** having the wall **411** that defines the space **412** therein, the cold storage material **42** that is disposed in the space **412** and supported by the supporter **41**, and the beams **43** that bridge the wall **411**. The supporter **41** and the beams **43** are formed of a material having superior thermal conductivity to the cold storage material **42**. The cold storage material **42** is in contact not only with the supporter **41** but also with the beams **43**. The heat of the battery cells **30** is transferred to the cold storage material **42** not only through the supporter **41** but also through the beams **43**.

[0083] Thus, the cold storage material **42** can efficiently absorb heat even with the low thermal conductivity. Therefore, the heat generated by the battery cells **30** can be dissipated effectively. As a result, it is possible to provide a battery pack **20** with high heat dissipation performance compared to a configuration without the beams **43**.

[0084] The cold storage member is lighter in weight than a circulation type cooler that performs cooling by circulating a refrigerant. This enables weight reduction while maintaining cooling performance, particularly for electric flying vehicles such as the eVTOL **10**. This makes it possible to increase the driving range.

[0085] In this embodiment, as an example, the beams **43** bridge the facing walls **411***a* and **411***b* of the supporter **41**. At least one of the facing walls **411***a*, **411***b* is in direct or indirect contact with the battery cell. In FIG. **4**, the heat transfer is indicated by arrows. As shown in FIG. **4**, heat is not only transferred from the facing walls **411***a* and **411***b* to the cold storage material **42**, but also transferred from the facing walls **411***a* and **411***b* to the cold storage material **42** through the beams **43**. When the battery cell is in contact with one of the facing walls **411***a* and **411***b* of the cold storage material **42**, the heat of the battery cell is transferred from the one of the facing walls **411***a* to the other through the beams **43**. Since heat is transferred to the entire area of the cold storage material **42**, the heat dissipation performance can be further improved.

[0086] In this embodiment, the beams **43** are pillars extending in one direction (i.e., the Y direction). The beams **43** having such a structure can be integrally formed with the supporter **41**. The cold storage member **40** can be made lighter while ensuring the cooling performance. The cold storage member **40** has the multiple beams **43**. The multiple beams **43** divide the space **412** into multiple sections. The multiple beams **43** divide the cold storage material **42** into multiple sections. Thus, heat is more easily transferred to the entire area of the cold storage material **42**.

[0087] In the present embodiment, at least a portion of the cold storage member **40** is interposed between and held by adjacent battery cells **30**. The cold storage member **40** is interposed between and held by the battery cells **30** from both sides in the X direction, which is the stacking direction. In this configuration, heat from the battery cells **30** is transferred to the cold storage members **40** from the side surfaces **30***c*. This side cooling structure increases the contact area and reduces the thermal resistance from the battery cell **30** to the cold storage material **42**, thereby further improving the heat dissipation performance. Furthermore, the beams **43** can suppress expansion of the battery cells **30** during charging, which helps reduce the occurrence of non-uniform electrochemical reactions. Additionally, since the beams **43** maintain the shape of the cold storage member **40**, the fixed structure of the battery cells **30** provided by the fixing members can be maintained.

[0088] FIG. **7** shows the results of a simulation showing the relationship between the presence or absence of the beams **43** and the amount of heat dissipated from the battery cells **30**. In this simulation, the battery cells **30** and the cold storage member **40** were arranged as shown in FIG. **4**. The cold storage material **42** is a paraffin-based latent heat storage material having a melting point at a predetermined temperature between 40° C. and 45° C., a thermal conductivity of 0.1 W to 1 W/(m.Math.K), and a latent heat of a predetermined value between 100 and 200 KJ/L. The supporter **41** and the beams **43** were made of aluminum having a thickness of 0.2 mm, and the pitch of the beams **43** was 2 mm. In FIG. **7**, the solid line indicates the results of a configuration having the beams **43**, and the dashed line indicates the results of a configuration without the beams **43**. The dot-dash line in FIG. **7** indicates a timing at which the cold storage material **42** starts to melt. FIG. **8** shows the phase state of the cold storage material **42** after 180 seconds in the above simulation. In FIG. **8**, the solid phase is indicated by dense dot hatching, and the liquid phase is indicated by sparse dot hatching.

[0089] As shown in FIG. **7**, the amount of heat dissipation increases after the start of melting due to the effect of latent heat. Moreover, it is clear that providing the beams **43** can increase the amount of heat dissipated from the battery cells **30**, that is, the amount of heat transferred to the cold storage member **40**. It is clear from FIG. **8** that providing the beams **43** reduces the residual solid phase of the cold storage material **42** during the transition to the liquid phase. In other words, it is clear that heat is transferred to almost the entire area of the cold storage material **42** by providing the beams **43**.

[0090] The cold storage material **42** may be a refrigerant such as water as described above. In this embodiment, the cold storage material **42** is a latent heat storage material. Latent heat storage material has a high specific heat capacity. Thus, the amount of the cold storage material **42** required to cool the batteries **15** can be reduced while ensuring the heat capacity (i.e., thermal mass). For example, it is possible to further increase the cruising range of the eVTOL **10**.

[0091] FIG. **9** shows a simulation result. The horizontal axis indicates the temperature T**0** ° C. before discharge, and the vertical axis indicates the required amount m. The required amount m is zero (0) at the bottom end and increases upward. This simulation compares water with a latent heat storage material. The specific heat capacity Cpcm of the latent heat storage material was set to 2 kJ/(kg.Math.K), and the latent heat L of the latent heat storage material was set to a predetermined value between 100 and 200 kJ/L. The heat capacity Ccell of the battery cell **30** is set to about 200 J/K, the heat generation amount Q is set to 12 kJ, and the upper limit temperature Tmax is set to 55K. In FIG. **9**, the solid line indicates the result for the latent heat storage material (i.e., PCM), and the dashed line indicates the result for water.

[0092] The average specific heat capacity Cave can be calculated using Equation 1. The required amount m can be calculated using Equation 2. Here, AT is the difference between the upper limit temperature Tmax and the temperature TO.

$$C\mathrm{ave}=(Cpcm-\Delta T+L)/\Delta T \qquad \text{(Equation 1)}$$

$$(C\mathrm{cell}+m.Math.C\mathrm{ave}).\mathrm{Math}.\Delta T=Q \qquad \text{(Equation 2)}$$

[0093] As shown in FIG. **9**, it is clear that by using the latent heat storage material, the required amount of the cold storage material **42** can be reduced while ensuring the necessary cooling performance.

[0094] In this embodiment, the phase transition temperature between the solid phase and the liquid phase in the latent heat storage material falls between 30° C. and 60° C. This allows the temperature of the battery cells **30** to be maintained at a temperature lower than the upper limit

temperature of the battery cells **30** assumed in the eVTOL **10**.
[0095] As an example, the latent heat storage material of this embodiment is an anhydrous carbon compound, specifically, a paraffin compound. Paraffin-based latent heat storage material exhibits minimal supercooling. Moreover, paraffin-based latent storage material does not corrode aluminum. Thus, it is suitable for combination use with the supporter **41** and beams **43** made of an aluminum-based material.
[0096] The cold storage material **42** is supported by the supporter **41**. The cold storage material **42** is injected into the space **412** of the supporter **41** and held by the supporter **41**. Thus, the cold storage member **40** including the cold storage material **42** can be easily separated from the battery cell **30**. The cold storage member **40** can be provided detachably to the battery cell **30**. This configuration allows the cold storage members **40** to be removed after the flight of the eVTOL **10**, and cooled back to the solid phase. For example, after the flight, the cold storage member **40** can be removed and replaced with another cold storage member **40** that has already phase transitioned to the solid phase. Replacement can reduce preparation time until the next flight.
[0097] <Modifications> The beams **43** bridge the wall (i.e., the facing walls **411***a*, **411***b*) that are in contact with the battery cells **30**, but the present disclosure is not limited to this. For example, the beams **43** may bridge between the side walls **411***c*. Even in this configuration, heat is transferred from the supporter **41** to the cold storage material **42** through the beams **43**. Therefore, the heat dissipation performance can be improved compared to a configuration without the beams **43**.
[0098] The cold storage material is a paraffin-based latent heat storage material as an example, but the cold storage material is not limited to this. The cold storage material may be a latent heat storage material that is water-soluble and has a pH adjusted to a value between 6 and 8. The above-mentioned hydrous corresponds to such latent heat storage material. By adjusting the pH to a neutral range, corrosion of aluminum can be suppressed. In addition, hydrous latent heat storage materials also exhibit minimal supercooling. In addition, the phase transition temperature is relatively easy to adjust.
[0099] The cold storage member **40** may have a protrusion, together with the beams **43**, that protrudes from the wall **411** but does not bridge the wall **411**. The protrusion is formed of the same material as the beams **43**. Thus, heat dissipation performance can be enhanced.
[0100] As shown in FIG. **10**, the supporter **41** may include an extension **411***d*. The extension **411***d* extends from the side wall **411***c* along the bottom surface **30***b*. The extension **411***d* extends in a direction perpendicular to the Y direction. The extension **411***d* may be in direct or indirect contact with the bottom surface **30***b* of the battery cell **30**. Heat is transferred to the extension **411***d* through at least one of the battery cells **30**, other portions of the supporter **41**, and the cold storage material **42**. Providing the extension **411***d* allows the heat absorbed by the cold storage material **42** to be easily released toward the bottom surface **30***b*. Thus, heat dissipation performance can be improved in a configuration in which a heat exchange element such as a heat dissipation fin is disposed on the bottom surface **30***b* of the battery cells **30**.
[0101] As shown in FIG. **11**, the cold storage member **40** may be arranged in a meandering manner. In FIG. **11**, each battery cell **30** has a cylindrical shape. The battery cells **30** are arranged in a staggered pattern in a top view in the Z direction. The cold storage member **40** is sandwiched between adjacent battery cells **30** to have a meandering shape. The beams bridge the facing walls **411***a* and **411***b* of the supporter **41**. The facing wall **411***a* is in contact with the battery cells **30** in the first row in the X direction, and the facing wall **411***b* is in contact with the battery cells **30** in the second row.
[0102] (Second Embodiment) This embodiment is a modification based on the preceding embodiment, and the description of the preceding embodiment are incorporated. In the previous embodiment, the cold storage members are in contact with the side surfaces of the battery cells. Alternatively, the cold storage member may be in contact with the bottom surface of the battery cells.

[0103] FIG. **12** shows the arrangement of the battery cells **30** and the cold storage member **40** in the battery pack **20** according to this embodiment. FIG. **12** corresponds to FIG. **4**. The cold storage member **40** is disposed on the bottom surface **30***b* of the battery cells **30**. Similar to the preceding embodiment, the cold storage member **40** includes the supporter **41** having the facing walls **411***a* and **411***b*, and the beams **43** bridging the facing walls **411***a* and **411***b*. The facing walls **411***a* of the supporter **41** is in direct or indirect contact with the bottom surfaces **30***b*. The cold storage member **40** is disposed to enclose all of the battery cells **30** when viewed in a plan view in the Z direction. The cold storage member **40** is in contact with the bottom surface **30***b* of each of the battery cells **30**. Other configurations are similar to those described in the preceding embodiment.
[0104] <Summary of Second Embodiment> In this embodiment, at least a portion of the cold storage member **40** is in contact with the bottom surfaces **30***b* of the battery cells **30**. The heat of the battery cells **30** is transferred to the cold storage material **42** not only through the supporter **41** but also through the beams **43**. Thus, the cold storage material **42** can efficiently absorb heat even with the low thermal conductivity. Therefore, the heat generated by the battery cells **30** can be dissipated effectively. Since the weight of the battery cells **30** acts on the cold storage member **40**, thermal contact is easily achieved.
[0105] Furthermore, since the cold storage member **40** is disposed on the bottom surfaces **30***b* of the battery cells **30**, the cold storage member **40** including the cold storage material **42** can be more easily separated from the battery cells **30** compared to a configuration in which it contacts the side surfaces **30***c* of the battery cells **30**. In other words, the cold storage member **40** can be easily detachable from the battery cells **30**.
[0106] Furthermore, providing the beams **43** can suppress deformation of the cold storage member **40** when the weight of the battery cells **30** acts on the cold storage member **40**. Since the beams **43** maintain the shape of the cold storage member **40**, the fixed structure of the battery cells **30** provided by the fixing members can be maintained.
[0107] <Modifications> The common cold storage member **40** (i.e., the single cold storage member **40**) is disposed for the multiple battery cells **30** as an example in this embodiment, but the present disclosure is not limited to this. The battery pack **20** may include multiple cold storage members **40**. For example, in a configuration including multiple battery stacks each formed by stacking the multiple battery cells **30**, the cold storage member **40** may be provided for each battery stack.
[0108] The configuration of the present embodiment can be combined with the preceding embodiments except for the configuration in which the cold storage members **40** are in contact with the side surfaces **30***c*. For example, the cold storage material **42** may be a latent heat cold storage material in a configuration in which the cold storage member **40** is in contact with the bottom surface **30***b*. The cold storage member **40** may include the beams **43** bridging the side walls **411***c*. The supporter **41** may include an extension **411***d* extending in a direction perpendicular to the Z direction.
[0109] (Third Embodiment) This embodiment is a modification based on the preceding embodiments, and the description of the preceding embodiments are incorporated. In the previous embodiments, the beams **43** are integrally formed with the supporter **41** by extrusion tubing. However, the structure of the supporter **41** and the beams **43** is not limited to this example. In this embodiment, a structure that allows further weight reduction is shown.
[0110] FIG. **13** is a top view of the cold storage member **40** in the battery pack **20** according to this embodiment. FIG. **13** corresponds to FIG. **6**. In FIG. **13**, the facing wall **411***b* on the near side is indicated by a dashed line. That is, in order to show the beam structure, the facing wall **411***b* is illustrated in a see-through manner.
[0111] The cold storage member **40** shown in FIG. **13** also includes the supporter **41**, the cold storage material **42**, and a beam **43**. The supporter **41** has the facing walls **411***a* and **411***b* as the wall **411**. The supporter **41** does not have side walls **411***c*. The beam **43** has a honeycomb structure. The beam **43** bridges the facing walls **411***a*, **411***b* in the X direction. The beam **43** is fixed to the flat

facing walls **411***a*, **411***b* by, for example, joining or bonding. The space **412** of the supporter **41** is partitioned by the facing walls **411***a*, **411***b* and the beam **43** into multiple sections each having a substantially regular hexagonal prism shape. Each section is filled with the cold storage material **42**. Other configurations are similar to those described in the preceding embodiment.
[0112] <Summary of Third Embodiment> In this embodiment, the beam **43** has a honeycomb structure. The honeycomb structure can reduce the weight of the beam **43** while ensuring the strength required to withstand the expansion of the battery cells **30**, the weight of the battery cells **30**, and pressure from the fixing members. Thus, the heat dissipation performance can be improved while the cold storage member **40**, and thus the battery pack **20** can be made lighter.
[0113] <Modifications> As shown in FIG. **14**, the cold storage member **40** may have a fin-shaped beam **43**. The fin shape is sometimes referred to as a corrugated plate shape. The cold storage member **40** has an inner fin structure in which the fin-shaped beam **43** is disposed inside the supporter **41**. This inner fin structure can reduce the weight of the beam **43** while ensuring the strength to withstand the expansion of the battery cells **30**, the weight of the battery cells **30**, and pressure from the fixing members. Thus, the heat dissipation performance can be improved while the cold storage member **40**, and thus the battery pack **20** can be made lighter.
[0114] The configuration described in this embodiment can be combined with any of the preceding configurations. For example, in the configuration in which the cold storage member **40** is in contact with the side surface **30***c* of the battery cell **30**, the cold storage member **40** may have the above-mentioned honeycomb structure or inner fin structure. In the configuration in which the cold storage member **40** is in contact with the bottom surface **30***b* of the battery cell **30**, the cold storage member **40** may have a honeycomb structure or an inner fin structure. In the cold storage member **40** having a honeycomb structure or an inner fin structure, the cold storage material **42** may be a latent heat cold storage material.
[0115] (Fourth Embodiment) This embodiment is a modification based on the preceding embodiments, and the description of the preceding embodiments are incorporated. In the previous embodiments, the pitch P**1** (i.e., the spacing) of the beams **43** is not specifically mentioned. In this embodiment, the pitch P**1** of the beams **43** will be described.
[0116] FIG. **15** is a diagram showing the relationship between the pitch P**1** of the beams **43** (see FIG. **5**) and the phase change time in the battery pack **20** according to this embodiment. FIG. **15** shows the simulation results using the Stefan solution. In this simulation, the thickness TH**1** of the cold storage material **42** (see FIG. **5**) was set to 15 mm. The phase change time is the time required to complete the change from solid to liquid phase, i.e., the time required to complete melting. The phase change time is zero (0) at the bottom end of FIG. **15** and increases upward.
[0117] If the pitch P**1** is less than 1 mm, it is difficult to form the beams **43** with high precision. Moreover, as the pitch P**1** approaches the thickness TH**1**, the change in the phase change time becomes smaller. When the pitch P**1** is further increased, the phase change time does not change, remaining at an approximately constant value. The effect of the pitch P**1** on the phase change time is significant up to 10 mm. In this embodiment, taking this result into consideration, the pitch P**1** of the beams **43** is set within the range of 1 mm to 10 mm. One of the dashed lines indicates the lower limit of 1 mm, and the other dashed line indicates the upper limit of 10 mm.
[0118] <Summary of Fourth Embodiment> As described above, in this embodiment, the pitch P**1** of the beams **43**, that is, the distance between adjacent beams **43**, is set between 1 mm and 10 mm. By setting the pitch P**1** within this range, the cold storage material **42** can be changed from the solid phase to the liquid phase in a short period.
[0119] If the pitch P**1** is shorter than the thickness TH**1**, the phase change time can be shortened. In other words, by making the pitch P**1** finer, heat can be easily distributed throughout the entire cold storage material **42**, and the residual during the transition from the solid phase to the liquid phase can be reduced. Thus, instead of the above range, the pitch P**1** may be set within the range between 1 mm, inclusive, and the thickness TH**1**, exclusive.

[0120] <Modifications> Although the pitch P**1** of the beams **43** is constant as an example in this embodiment, the present disclosure is not limited thereto. The pitch P**1** may vary depending on the position. For example, as shown in FIG. **16**, the pitch P**1** of the beams **43** may be narrower as they approach the electrode terminals **31**P, **31**N. The battery cells **30** tend to have a concentration of current near the electrode terminals **31**P and **31**N. In other words, portions near the electrode terminals **31**P, **31**N are prone to becoming high-temperature areas. According to the above arrangement, heat from the electrode terminals **31**P, **31**N can be effectively dissipated, and the electrode terminals **31**P, **31**N can be prevented from becoming too hot. The pitch P**1** of the beam may be set between 1 mm and 10 mm, and be narrower as the beam approaches the electrode terminals **31**P, **31**N.
[0121] (Fifth Embodiment) This embodiment is a modification based on the preceding embodiments, and the description of the preceding embodiments are incorporated. This embodiment features a configuration that allows for even easier detachability.
[0122] FIG. **17** is a cross-sectional view showing the battery pack **20** according to the present embodiment. FIG. **17** shows a fixing structure of the battery pack **20**. In FIG. **17**, illustration of a part of the battery cells **30** is omitted. The battery pack **20** is fixed to a bracket **100**. The battery pack **20** is fixed to the aircraft via the bracket **100**.
[0123] The bracket **100** has an opening **101**. The cold storage member **40** is fixed to the bottom wall **50***a* of the housing **50** through the opening **101**. The cold storage member **40** is fixed to the housing **50** by, for example, adhesive or bolt fastening. The cold storage member **40** is disposed so that the facing wall **411***a* is in contact with the bottom wall **50***a*. The cold storage member **40** is disposed to enclose the battery cells **30** when viewed in a plan view in the Z direction. There is a TIM **60** on the inner surface of the bottom wall **50***a*. The TIM overlaps with the cold storage member **40** in the plan view. The multiple battery cells **30** are disposed on the bottom wall **50***a* via the TIM **60**. The heat of the battery cells **30** is transferred to the cold storage member **40** via the TIM **60** and the metal housing **50** (i.e., the bottom wall **50***a*).
[0124] <Summary of Fifth Embodiment> In this embodiment, the cold storage member **40** is provided detachably to the housing **50**. In other words, the cold storage member **40** is provided detachably with respect to the other elements constituting the battery pack **20**. The cold storage member **40** is provided detachably to the battery cell **30**. For example, the cold storage member **40** can be removed from other elements of the battery pack **20** by releasing the bolt fastening. Thus, it is possible to improve the heat dissipation performance and the ease of attachment and detachment.
[0125] Because of this easy detachability, the cold storage member **40** may be removed from the eVTOL **10** after the flight, cooled, and returned back to the solid phase. The cold storage member **40** may be removed after the flight and replaced with another cold storage member **40** that has cooled and transitioned back to the solid phase. Such replacement can eliminate loss of cooling time.
[0126] (Sixth Embodiment) This embodiment is a modification based on the preceding embodiments, and the description of the preceding embodiments are incorporated.
[0127] As shown in FIG. **18**, multiple battery cells **30** and multiple cold storage members **40** are pressed and fixed by a pressing member **51** serving as a fixing member. The pressing member **51** is a belt-like band. In this embodiment, two pressing members **51** press and fix the multiple battery cells **30** and the multiple cold storage members **40** in the stacking direction (i.e., the X direction). As described in the preceding embodiments, the beams **43** extend in the stacking direction and bridge the facing walls **411***a*, **411***b*.
[0128] FIG. **19** is a cross-sectional view of the cold storage member **40** before being filled with the cold storage material **42** in this embodiment. FIG. **20** is an enlarged diagram of a part of FIG. **19**. The supporter **41** includes a cylindrical passage portion **80** extending in the Y direction. The passage portion **80** defines a passage for filling the space **412** with gas or liquid from the outside.
[0129] As shown in FIG. **20**, the passage portion **80** defines a hollow space extending in the Y

direction, and the hollow space corresponds to a passage for filling the space with gas or liquid. The passage portion **80** is open at both the upper end and the lower end in the Y direction, and the lower end opens toward the space **412**. The passage portion **80** is provided at an end portion of the supporter **41**. The cold storage material, inert gas, and the like can be injected into the cold storage member **40** through the hollow space of the passage portion **80** from the outside. The supporter **41** may have only one passage portion **80** or multiple passage portions **80**. As an example, the passage portion **80** is formed of a metal. The upper end of the passage portion **80** in the Y direction may be closed by crimping after the cold storage member **40** is filled with the cold storage material **42** and the inert gas.

[0130] The supporter **41** includes a gas injection passage **80***a*, a filling passage **80***b*, and a lid **70**. The gas injection passage **80***a* is a passage through which an inert gas can be injected into the space **412**. The hollow space of the passage portion **80** extending in the Y direction serves as the gas injection passage **80***a*. The space **412** of the cold storage member **40** is filled with an inert gas together with the cold storage material **42**. The cold storage member **40** may have only one gas injection passage **80***a* or multiple gas injection passages **80***a*. The gas injection passage **80***a* may be a gas exhaust passage **80***c*, which is a passage for exhausting gas.

[0131] The lid **70** closes the space **412** so that the inert gas and the cold storage material **42** filling the space **412** do not leak out of the cold storage member **40**. The lids **70** are provided on the upper and lower parts of the supporter **41**. The lid **70** is made of a resin material.

[0132] The filling passage **80***b* is a passage through which the cold storage material **42** is injected into the space **412**. The hollow space of the passage portion **80** extending in the Y direction serves as the filling passage **80***b*. The supporter **41** may define only one filling passage **80***b*, or multiple filling passages **80***b*. The gas injection passage **80***a* and the filling passage **80***b* are commonly provided as a common passage. In this embodiment, the beams **43** each have a flat plate shape extending in the XY plane. The plate surface of the beam **43** extends in a direction in which the filling passage **80***b* opens toward the space **412** (i.e., the Y direction).

[0133] The space **412** includes multiple beam paths **412***a* partitioned by the beams **43**, and communication paths **412***b* that fluidly connect between the beam paths **412***a*. The beam paths **412***a* extend approximately parallel to the direction in which the plate surface of the beams **43** extend (i.e., the Y direction). The cold storage material **42** is injected into the beam paths **412***a* through the filling passage **80***b*.

[0134] The communication paths **412***b* are formed, for example, by cutting out the beams **43** as shown in FIG. **21**. The communication paths **412***b* may be formed by a method other than cutting out the beams **43**, so long as the communication paths **412***b* are configured to fluidly connect between the beam paths **412***a*. Each of the beams **43** has the multiple communication paths **412***b*. The communication paths **412***b* are defined at different positions in the direction in which the cold storage material **42** moves to fill the beam paths **412***a* (i.e., the Y direction). In other words, the communication paths **412***b* are arranged in parallel in the direction in which the filling passage **80***b* opens toward the space **412** (i.e., the Y direction). The direction in which the cold storage material **42** moves to fill the beam paths **412***a* can also be interpreted as the direction in which the filling passage **80***b* extends or the direction in which the filling passage **80***b* opens toward the space **412**.

[0135] In this embodiment, as shown in FIG. **19**, the communication paths **412***b* are provided at the upper end and the lower end of the supporter **41** in a filling direction in which the cold storage material **42** flows during injection into the space **412**. FIG. **22** is a diagram showing the cold storage member **40** after the cold storage material **42** is injected into the space **412**. As shown in FIG. **22**, the communication paths **412***b* located at the lower end of the supporter **41** allow the portions of the space **412** filled with the cold storage material **42** to fluidly communicate with each other. The communication paths **412***b* located at the upper end of the supporter **41** faces the opening of the filling passage **80***b*, and fluidly connects the portions of the space **412** filled with the inert gas to each other.

[0136] One of the communication paths **412***b* is provided at the lower end in the Y direction of the supporter **41**, but may be provided at a position other than the lower end. The communication path **412***b* may be provided between the center and the lower end of the supporter **41** in the Y direction. The communication path **412***b* may be provided at a position that can fluidly connect between the portions which are filled with the cold storage material **42**.
[0137] One of the communication paths **412***b* is provided at the upper end of the supporter **41** in the Y direction, but may be provided at a position other than the upper end. The communication path may be provided between the upper end and the center of the supporter **41** in the Y direction. The portion of the cold storage member **40** that is not filled with the cold storage material **42** is filled with an inert gas. Instead of the inert gas, a gas such as air may be injected.
[0138] Here, a method for replacing the air remaining in the space **412** with an inert gas after the cold storage material **42** is injected into the cold storage member **40** through the passage portion **80** (i.e., the filling passage **80***b*) will be described. The passage portion **80** (i.e., the gas injection passage **80***a*, the gas exhaust passage **80***c*, and the filling passage **80***b*) is connected to an inert gas cylinder by piping via a three-way valve. The three-way valve serves as three valves. The valve connected to the inert gas cylinder is referred to as a first valve, the valve connected to the passage portion **80** is referred to as a second valve, and the valve connected to a check valve is referred to as a third valve.
[0139] When replacing the gas, the first and second valves are opened and an inert gas is introduced into the space **412** via the passage portion **80** (i.e., the gas injection passage **80***a*). Thereafter, the first valve is closed and the second and third valves are opened, and the gas remained in the space **412** (i.e., residual air and inert gas) is released through the passage portion **80** (i.e., the gas exhaust passage **80***c*). By repeating this process several times, the air remaining in the cold storage member **40** can be replaced with the inert gas.
[0140] <Summary of Sixth Embodiment> In this embodiment, the pressing member **51** presses and fixes the battery cells **30** and the cold storage members **40** in the stacking direction. The beams **43** extend in the stacking direction to bridge different walls. Here, if the multiple battery cells **30** and the multiple cold storage members **40** are pressed and fixed by the pressing member **51**, the supporter **41** may be buckled. In this embodiment, the beams **43** extend in the stacking direction to bridge the walls **411**, thereby preventing the supporter **41** from being buckled.
[0141] In this embodiment, the space **412** is filled with the cold storage material **42** and an inert gas. If the space **412** is filled with only the cold storage material **42**, the beams **43** may be damaged when the cold storage material **42** expands in volume. The damage for the beams **43** can be reduced by not filling the space **412** completely with the cold storage material **42**, but filling the space **412** partially with the cold storage material **42** and the rest with an inert gas. Filling the space **412** with an inert gas can reduce the risk of combustion compared to filling the space **412** with air.
[0142] In this embodiment, the supporter **41** has the gas injection passage **80***a* for filling the space **412** with an inert gas. This allows the inert gas to be injected into the space **412** through the gas injection passage **80***a* during the manufacturing process of the cold storage member **40**. Thus, the air remaining in the cold storage member **40** can be pushed out by the inert gas and discharged. That is, the gas present in the space **412** together with the cold storage material **42** can be replaced from air to an inert gas.
[0143] In this embodiment, the filling passage **80***b* through which the cold storage material **42** is injected into the space **412** is provided. The beams **43** each have a plate shape, and the plate surface of the beams **43** extends in the direction in which the filling passage **80***b* opens toward the space **412**. If the plate surface of the beams **43** extends in a direction perpendicular to the opening direction of the filling passage **80***b* toward the space **412**, contrary to this embodiment, the cold storage material **42** will flow against the plate surface of the beams **43** during injection. At this time, most of the pressure will be applied to the beams **43**. In the present disclosure, the cold storage material **42** flows from the filling passage **80***b* in the direction in which the beams **43**

extend, so that most of the pressure is applied to the wall **411**, not to the beams **43**. This prevents excessive pressure from being applied to the beams **43** and causing the beams **43** to be damaged.
[0144] In this embodiment, the space **412** is filled with the cooling storage material **42** and an inert gas. The supporter **41** has the gas injection passage **80***a* and the filling passage **80***b* that are commonly provided as a single common passage. This allows a simpler structure compared to a case where the gas injection passage **80***a* and the filling passage **80***b* are provided separately.
[0145] In this embodiment, the space **412** includes the beam paths **412***a* and the communication paths **412***b* that fluidly connect the beam paths **412***a* to one another. When the cold storage material **42** is injected, one of the beam paths **412***a* near the opening of the filling passage **80***b* is firstly filled with the cold storage material **42**. Then, when the cold storage material **42** is further injected, the cold storage material **42** flows into the adjacent beam path **412***a* through the communication path **412***b*. That is, when filling the cold storage material **42** into the space **412** inside the cold storage member **40**, the cold storage material **42** can be distributed more efficiently to the beam paths **412***a* through the single filling passage **80***b*. This can improve the efficiency of filling the cold storage material **42**.
[0146] In this embodiment, the space **412** is filled with gas together with the cold storage material **42**. The communication paths **412***b* fluidly connect the portions of the beam paths **412***a* filled with the cold storage material **42** to each other. The filling amount may vary among the beam paths **412***a* immediately after the injection of the cold storage material **42** is completed. Even in this case, since the communication paths **412***b* are located in the portion filled with the cold storage material **42**, the cold storage material **42** is distributed by its own weight through the communication paths **412***b* as time passes. This makes the amount of the cold storage material **42** in each beam path **412***a* uniform, thereby suppressing variations in cooling efficiency.
[0147] <Modifications> FIG. **23** is a diagram illustrating a modification. In FIG. **23**, the illustration of the passage portion **80** is omitted. As shown in FIG. **23**, the battery cells **30** are disposed adjacent to the cold storage member **40** with the electrode terminals **31**P, **31**N facing downward in the Z direction. In this modified example, the downward direction in the Z direction indicates the direction of gravity, and the upward direction in the Z direction indicates the direction opposite to the direction of gravity. The space **412** of the cold storage member **40** are filled with gas and the cold storage material **42**. The filled cold storage material **42** accumulates in the lower part of the cold storage member **40** due to gravity, while the gas accumulates in the upper part of the cold storage member **40**. In this modified example, the dimensions of the battery cell **30** and the cold storage member **40** in the Y direction and the Z direction are substantially equal.
[0148] The electrode terminals **31**P, **31**N facing downward in the Z direction means that the electrode terminals **31**P, **31**N are disposed below half of the battery cells **30**. The electrode terminals **31**P, **31**N may be disposed below one third of the battery cells **30**.
[0149] In this modification, the vicinity of the electrode terminals **31**P, **31**N of the battery cell **30** (hereinafter also referred to as the electrode terminal vicinity) is adjacent to the portion of the cold storage member **40** where the cold storage material **42** is filled. The electrode terminal vicinity refers to the periphery of the portions of the battery cells **30** adjacent to the electrode terminals **31**P, **31**N. The portion of the cold storage member **40** filled with the cold storage material **42** is disposed near the high temperature portion of the battery cell **30** (i.e., the electrode terminal vicinity). In other words, the portion of the cold storage member **40** filled with the gas is not disposed near the high temperature portion of the battery cells **30** (i.e., the electrode terminal vicinity). In this modification, the dimensions of the battery cells **30** and the cold storage member **40** in the Y direction and the Z direction are substantially equal, but the present disclosure is not limited thereto. As long as the electrode terminal vicinity of the battery cells **30** is disposed adjacent to the portion of the cold storage member **40** filled with the cold storage material **42**, the dimensions can be changed as appropriate.
[0150] Heat generated from the electrode terminals **31**P, **31**N of the battery cells **30** increases the

temperature of the electrode terminal vicinity. Furthermore, when the cold storage member **40** is filled with gas, the gas accumulates in the upper portion of the cold storage member **40** due to buoyancy. Thus, if the battery cells **30** are placed adjacent to the cold storage member **40** with the electrode terminals **31**P, **31**N facing up, contrary to the present disclosure, the area around the electrode terminals, which becomes hot, will be adjacent to the upper part of the cold storage member **40**, where gas accumulates. This causes an insufficient cooling of the battery cells **30**. Therefore, in this modification, the battery cells **30** are disposed adjacent to the cold storage member **40** with the electrode terminals **31**P, **31**N facing downward. According to this modified example, it is easy to ensure that the area near the electrode terminals of the battery cell **30** does not come into contact with the upper portion of the cold storage member **40**, which is filled with gas.
[0151] The battery cell **30** may be placed adjacent to the cold storage member **40** with the electrode terminals **31**P, **31**N disposed horizontally. Horizontal refers to a state in which the battery cells **30** in FIG. **23** are rotated ±90 degrees on the YZ plane, for example. When the battery cells **30** are placed horizontally adjacent to the cold storage member **40**, the electrode terminals **31**P, **31**N protrude in the Y direction. In other words, the electrode terminals **31**P, **31**N protrude in a direction perpendicular to the direction in which the battery cells **30** and the cold storage member **40** face each other, and in a direction perpendicular to the up-down direction. In this case as well, the area of the battery cells near the electrode terminals **31**P, **31**N is positioned adjacent to the portion of the cold storage member **40** filled with the cold storage material **42**, so that similar effects as those in the above-mentioned modified example can be obtained.
[0152] Although the electrode terminals **31**P and **31**N protrude from the top surface **30***a*, the electrode terminals **31**P and **31**N do not have to protrude from the same surface. One of the electrode terminals **31**P, **31**N may protrude from the top surface **30***a*, and the other may protrude from the bottom surface **30***b*. In this case as well, by arranging the battery cells **30** adjacent to the cold storage member **40** with the electrode terminals **31**P, **31**N lying horizontally, the similar effects as those in in the above-mentioned modified example can be obtained.
[0153] Placing the electrode terminals **31**P, **31**N horizontally means that the electrode terminals **31**P, **31**N are disposed below the upper one third of the battery cells **30**.
[0154] The direction in which the pressing member **51** presses the battery cells **30** and the cold storage members **40** is not limited to the stacking direction. The pressing member **51** may also press the battery cells **30** and the cold storage member **40** in other directions to fix them.
[0155] Although the space **412** is filled with an inert gas together with the cold storage material **42**, it is not necessary to fill the space with an inert gas. The space **412** may be filled with something other than an inert gas (e.g., air).
[0156] Although the plate surface of the beams **43** extend in a direction in which the filling passage **80***b* opens toward the space **412**, the present disclosure is not limited to this. The plate surface of the beams **43** may extend in a direction perpendicular to the opening direction toward the space **412**.
[0157] The gas injection passage **80***a* and the filling passage **80***b* do not have to be a common passage. The gas injection passage **80***a* and the filling passage **80***b* may be provided separately.
[0158] Although the space **412** includes the communication paths **412***b* that fluidly connect the multiple beam paths **412***a* to each other, the communication paths **412***b* do not necessarily have to be provided.
[0159] The communication paths **412***b* may fluidly connect the portions of the beam paths **412***a* that are not filled with the cold storage material **42** to each other.
[0160] The battery cells **30** may be disposed adjacent to the cold storage member **40** with the electrode terminals **31**P, **31**N facing upward in the Z direction.
[0161] (Other embodiments) The disclosure in this specification, the drawings, and the like is not limited to the illustrated embodiments. The present disclosure encompasses the illustrated embodiments and modifications based on them by those skill in the art. For example, the

disclosures are not limited to the combinations of components and/or elements shown in the embodiments. The disclosure may be implemented in various combinations. The present disclosures may include additional parts which may be added to the embodiments. The disclosures encompass those in which the components and/or elements of the embodiments are omitted. The disclosures include replacements or combinations of components and/or elements between one embodiment and another embodiment. The disclosed technical scope is not limited to the descriptions of the embodiments. The disclosed technical scopes should be indicated by the descriptions of the claims, and should be further understood to include all modifications within the meanings and range equivalent to the descriptions of the claims.
[0162] The disclosures in the specification, drawings and the like are not limited by the descriptions of the claims. The disclosures in the specification, the drawings, and the like encompass the technical ideas described in the claims, and further extend to a wider variety of technical ideas than those in the claims. Therefore, various technical ideas can be extracted from the disclosure of the specification, the drawings, and the like without being limited to the description of the claims.
[0163] When an element or layer is referred to as being “on,” “coupled,” “connected,” or “combined,” it may be directly on, coupled, connected, or combined to the other element or layer, or further, intervening elements or layers may be present. In contrast, when an element or a layer is described as “disposed directly above” or “directly connected”, an intervening element or an intervening layer is not present. Other terms used to describe the relationships between elements (for example, “between” vs. “directly between”, and “adjacent” vs. “directly adjacent”) should be interpreted similarly. As used herein, the term “and/or” includes any combination and all combinations relating to one or more of the related listed items. For example, the term A and/or B includes only A, only B, or both A and B.
[0164] The number of the battery cells **30** included in the battery pack **20** is not limited to the above example. For example, only one battery cell **30** may be provided.
[0165] A portion of the cold storage member **40** may be in contact with the side surface **30***c* of the battery cell **30**, and another portion may be in contact with the bottom surface **30***b*.

Claims

1. A battery pack to be installed in an electric mobile object, the battery pack comprising: a battery cell; and a cold storage member configured to cool the battery cell, wherein the cold storage member includes: a supporter that has a wall defining a space therein; a cold storage material that is disposed in the space and supported by the supporter; and a beam that bridges the wall, and the supporter and the beam are made of a material that has a better thermal conductivity than the cold storage material.
2. The battery pack according to claim 1, wherein the wall includes two facing walls that face each other, the beam bridges the two facing walls, at least one of the two facing walls is directly or indirectly in contact with the battery cell.
3. The battery pack according to claim 2, wherein the beam has a honeycomb structure, a fin structure, or a pillar structure in which multiple pillars extend in one direction.
4. The battery pack according to claim 1, wherein the battery cell is one of battery cells, at least a part of the cold storage member is interposed between and held by adjacent ones of the battery cells.
5. The battery pack according to claim 1, wherein at least a part of the cold storage member is in contact with a bottom surface of the battery cell.
6. The battery pack according to claim 1, wherein the cold storage material is a latent heat storage material.
7. The battery pack according to claim 6, wherein the latent heat storage material has a phase

transfer temperature that falls within a range between 30° C. and 60° C.

8. The battery pack according to claim 7, wherein the latent heat storage material is an anhydrous carbon compound.

9. The battery pack according to claim 6, wherein the latent heat storage material is water-soluble and adjusted to have a pH of 6 to 8.

10. The battery pack according to claim 1, wherein the beam is one of beams, and a distance between adjacent ones of the beams falls within a range between 1 mm to 10 mm.

11. The battery pack according to claim 1, wherein the battery cell includes an electrode terminal, the beam is one of beams, and a distance between adjacent ones of the beams becomes narrower as the beams get closer to the electrode terminal.

12. The battery pack according to claim 1, wherein at least a part of the cold storage member is detachable from the battery cell.

13. The battery pack according to claim 1, further comprising a pressing member configured to press and fix the battery cell and the cold storage member, wherein the battery cell is one of battery cells, the cold storage member is one of cold storage members, the battery cells and the cold storage members are alternatively arranged in a predetermined stacking direction and fixed by the pressing member, and the beam extends in the predetermined stacking direction to bridge the wall.

14. The battery pack according to claim 1, wherein the space is filled with the cold storage material and an inert gas.

15. The battery pack according to claim 14, wherein the supporter defines a gas injection passage through which the inert gas is injected into the space.

16. The battery pack according to claim 1, wherein the supporter defines a filling passage through which the cold storage material is injected into the space, the filling passage opens toward the space in an opening direction, and the beam has a plate shape and has a plate surface extending in the opening direction.

17. The battery pack according to claim 1, wherein the space is filled with the cold storage material and an inert gas, the supporter defines a gas injection passage through which the inert gas is injected into the space and a filling passage through which the cold storage material is injected into the space, and the gas injection passage and the filling passage are commonly provided as a common passage.

18. The battery pack according to claim 1, wherein the space includes beam paths partitioned by the beam and a communication path fluidly connecting between the beam paths.

19. The battery pack according to claim 18, wherein the cold storage material flows through the beam paths in a filling direction during injection of the cold storage material into the space, the communication path is one of communication paths, and the communication paths are defined at different positions of the beam in the filling direction.

20. The battery pack according to claim 18, wherein the space is filled with the cold storage material and a gas, the beam paths have filled portions that are filled with the cold storage material, and the communication path fluidly connects between the filled portions.

21. The battery pack according to claim 1, wherein the space is filled with the cold storage material and a gas, the battery cell has an electrode terminal, the battery cell has a portion from which the electrode terminal protrudes, the cold storage member has a portion which is filled with the cold storage material, and the portion filled with the cold storage material is adjacent to the portion from which the electrode terminal protrudes.