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(54) **HEAT EXCHANGE APPARATUS**

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(57) **ABSTRACT**

A heat exchange apparatus includes: a main body including a top panel and a bottom panel, the top panel superposed on top of the bottom panel to define a heat carrier passage therebetween; a bracket fixed to an outside surface of the top panel; a shaft member fixed to the bracket; a temperature sensor support board including a penetration portion penetrated by the shaft member; a temperature sensor fixed to the temperature sensor support board; and a pressing member disposed at a distal end of the shaft member penetrating through the temperature sensor support board and pressing down the temperature sensor support board onto the bracket. The shaft member penetrating through the temperature sensor support board is disposed at a position to face the heat carrier passage via the top panel.

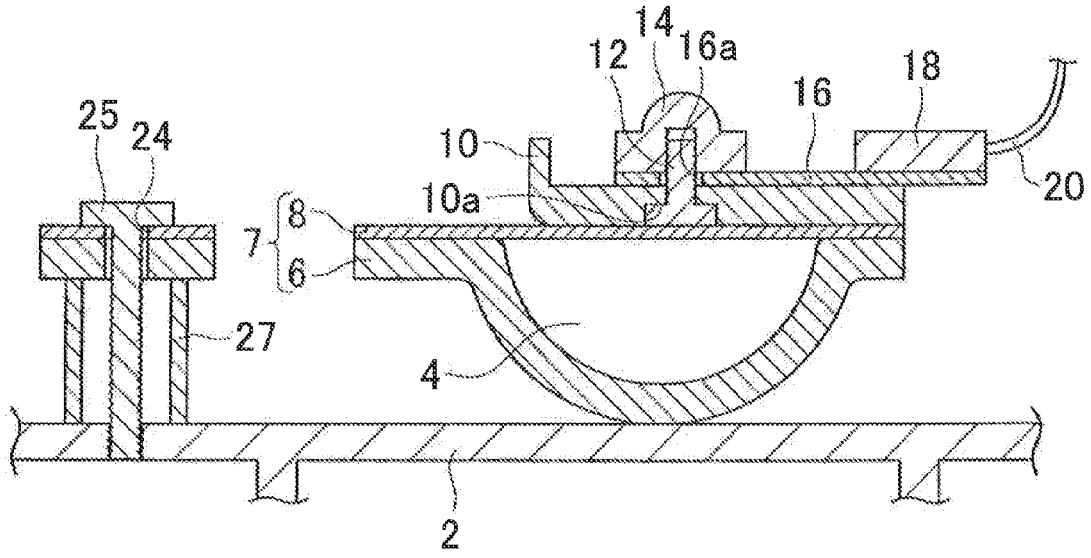


FIG. 1

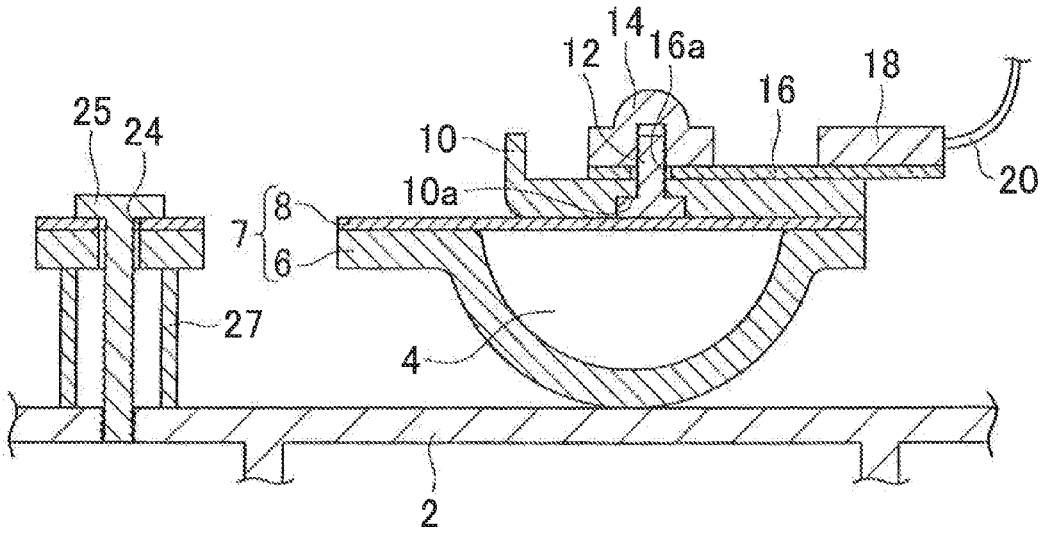


FIG. 2

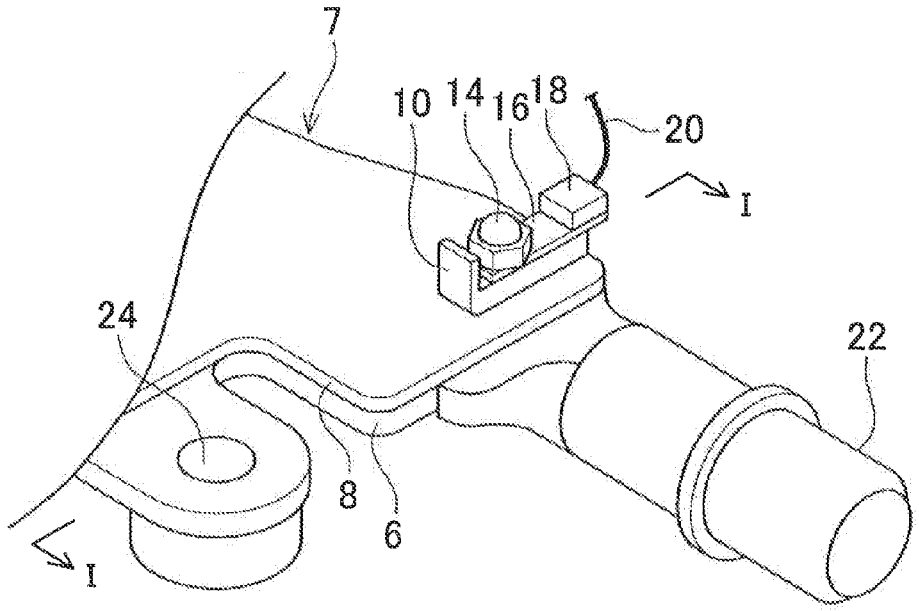


FIG. 3
[RELATED ART]

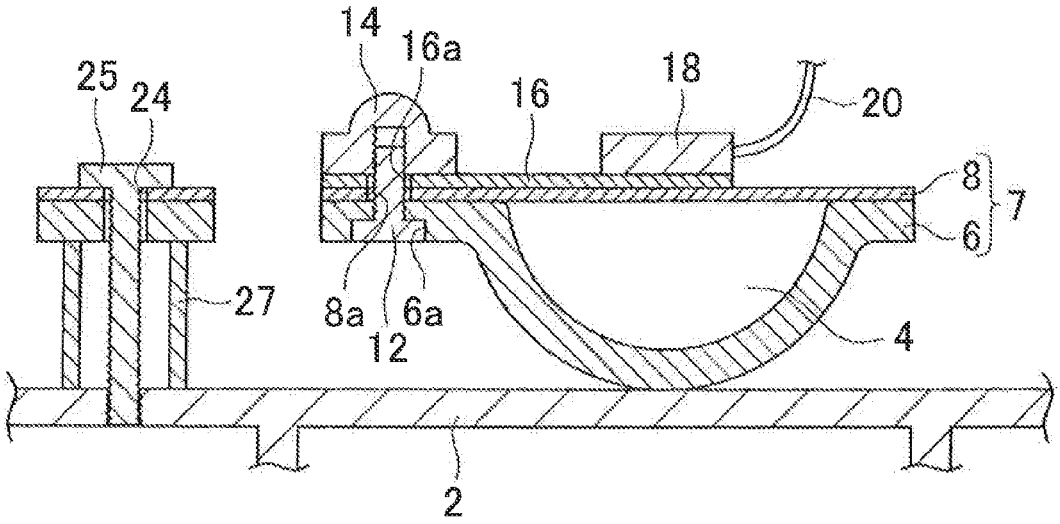
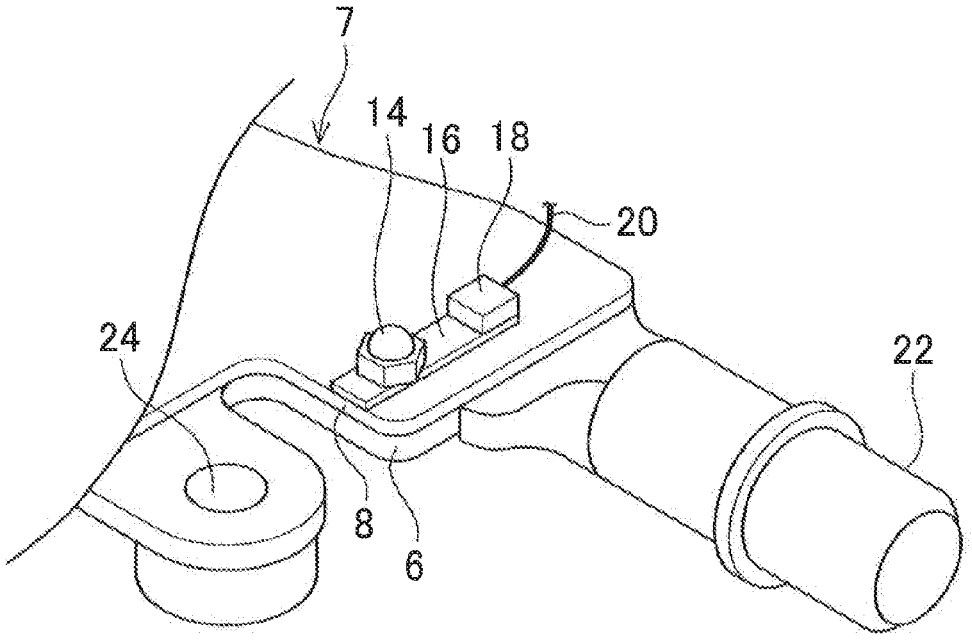


FIG. 4
[RELATED ART]



HEAT EXCHANGE APPARATUS

INCORPORATION BY REFERENCE

[0001] The disclosure of Japanese Patent Application No. 2011-259387 filed on Nov. 28, 2011 including the specification, drawings and abstract is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] There has been known a heat exchange apparatus designed to cool, for example, a semiconductor device which generates heat when operating. The heat exchange apparatus is mounted with the semiconductor device on an outside surface of a heat exchanger body with a liquid coolant flowing therethrough, thus cooling the semiconductor device with the liquid coolant. This specification discloses an apparatus which exchanges heat between a heat carrier flowing through the heat exchanger body and a device disposed on the outside of the heat exchanger body. The heat carrier is not limited to liquid and may be a gaseous medium or an intermediate medium between gas and liquid. More specifically, the heat exchange apparatus of the invention may be a heat exchange apparatus for cooling devices or a heat exchange apparatus for heating devices.

[0004] 2. Description of the Related Art

[0005] The heat exchange apparatus often requires exact detection of the temperature of the heat carrier. Particularly, in a case where a semiconductor device for regulating electric power supplied to a vehicle-mounted traction motor is cooled by heat exchange between the semiconductor device and the liquid coolant, it is extremely necessary to detect the temperature of the liquid coolant exactly. Furthermore, in a case where the temperature of the liquid coolant fluctuates, it is extremely necessary to instantaneously detect the temperature change.

[0006] However, it is difficult to dispose a temperature sensor for detecting the heat carrier temperature within the heat exchanger body. The temperature sensor is normally disposed on the outside of the heat exchanger body. In the case where the temperature sensor is disposed on the outside of the heat exchanger body, various factors affect the output of the temperature sensor. In exact observation, the temperature of the heat carrier, the temperature of a wall of the heat exchanger body, and the temperature of a device exchanging heat with the heat carrier vary from one another. Various considerations must be given to the detection of the heat carrier temperature using the temperature sensor disposed on the outside of the heat exchanger body while eliminating the influences of the temperature of the device exchanging heat with the heat carrier.

[0007] FIG. **3** and FIG. **4** show a surrounding structure of a temperature sensor of a heat exchange apparatus disclosed in the description and the drawings of Japanese Patent Application No. 2010-268115 (JP 2010-268115). However, this patent application has not been laid open yet (note: Although this patent application was not yet laid open on Nov. 28, 2011 when the application of this invention was filed, this patent application was laid open afterward on Jun. 21, 2012 as Japanese Patent Application Publication No. 2012-119501 (JP 2012-119501 A)). The heat exchange apparatus includes a heat exchanger body **7** in which a top panel **8** is superposed on a bottom panel **6** to define a heat carrier passage **4** therebetween, A temperature sensor **18** is fixed to the heat exchanger body **7** as follows. The bottom panel **6** and the top panel **8** are formed with through-holes **6***a*, **8***a* at places of superposition, the through-holes **6***a*, **8***a* permitting a bolt **12** to penetrate therethrough. The bolt **12** is press-inserted into the through-hole **6***a* and fixed therein. A shank of the bolt **12** penetrates through the through-hole **8***a* of the top panel **8**. The temperature sensor **18** is fixed to a temperature sensor support board **16**. The temperature sensor support board **16** is formed with a through-hole **16***a* to permit the shank of the bolt **12** to penetrate therethrough. The shank of the bolt **12** is inserted through the through-hole **16***a* of the temperature sensor support board **16** and a nut **14** is screwed on a tip of the bolt **12**, whereby the temperature sensor support board **16** is clamped and fixed between the nut **14** and the top panel **8**. The temperature sensor **18** is fixed at a position to face the heat carrier passage **4** via the top panel **8**.

[0008] A heat exchange apparatus mounted with a temperature sensor is also disclosed in Japanese Patent Application Publication No, 2002-305010 (JP 2002-305010 A). The heat exchange apparatus of JP 2002-305010 A employs a logic plate having the temperature sensor embedded in the plate.

[0009] The temperature sensor fixing technique shown in FIG. **3** and FIG. **4** has a problem in detecting the temperature of the heat carrier without response delay, FIG. **3** shows the temperature sensor **18** which is fixed at the position to face the heat carrier passage **4** via the top panel **8**. However, the temperature sensor **18** is not in intimate contact with the top panel **8**. More exactly, an area of the temperature sensor support board **16** that covers a bottom face of the temperature sensor **18** is not in intimate contact with the top panel **8**. Therefore, the amount of heat transferred along a heat transfer passage going from the heat carrier in the heat carrier passage **4**→the top panel **8**→the temperature sensor **18** is unexpectedly small. Measurement results actually show that the amount of heat transferred along a heat transfer passage going from the heat carrier in the heat carrier passage **4**→the top panel **8**→the bolt **12**→the temperature sensor support board **16**→the temperature sensor **18** is rather greater than the above amount of heat. It was found that the latter heat transfer passage has less heat resistance because the bolt **12** and nut **14** bring the top panel **8** and the temperature sensor support board **16** into intimate contact at areas around the bolt **12** and nut **14**.

[0010] According to the temperature sensor fixing technique shown in FIG. **3** and FIG. **4**, the heat transfer passage, as the main heat transfer passage, going from the heat carrier in the heat carrier passage **4**→the top panel **8**→the bolt **12**→the temperature sensor support board **16**→the temperature sensor **18** has such a long passage length that it takes a long time for temperature change of the heat carrier to be transferred to the temperature sensor **18**. In the temperature sensor fixing technique shown in FIG. **3** and FIG. **4**, response delay during the measurement of temperature is not negligible. The heat is transferred to the bolt **12** not only from the top panel **8** but also from the bottom panel **6** while the bottom panel **6** is in contact with a wall of a casing **2**. The temperature of the heat carrier differs from that of the wall of the casing **2**. According to the temperature sensor fixing technique shown in FIG. **3** and FIG. **4**, it is also found that the temperatures of the wall of the casing **2** and the like affect the results of temperature measurement. With the use of the logic plate

disclosed in JP 2002-305010 A, it is still difficult to achieve the exact and quick detection of the temperature of the heat carrier.

SUMMARY OF THE INVENTION

[0011] This specification discloses a heat exchange apparatus which is the result of improvement in the temperature sensor fixing technique and is capable of exact and quick detection of the temperature of the heat carrier (capable of outputting temperature measurement results following the temperature change of the heat carrier quick enough to make time delay negligible).

[0012] According to one aspect of the invention, a heat exchange apparatus includes: a main body having a top panel and a bottom panel, the top panel superposed on top of the bottom panel to define a heat carrier passage therebetween; a temperature sensor fixed to a temperature sensor support board; and a fixing member for fixing the temperature sensor support board to the top panel and fixed to an outside surface of the top panel at a position to face the heat carrier passage via the top panel. According to the above heat exchange apparatus, the main heat transfer passage going from the heat carrier in the heat carrier passage→the top panel→the fixing member→the temperature sensor support board is minimized in the passage length. Hence, the temperature change of the heat carrier is quickly transferred to the temperature sensor. Further, the temperature sensor is less affected by temperatures of elements other than the heat carrier in the heat carrier passage. Thus, the temperature sensor can achieve the exact and quick detection of the temperature of the heat carrier.

[0013] In the heat exchange apparatus according to another aspect of the invention, the temperature sensor may also be deviated from as position to face the heat carrier passage via the top panel as a result of fixing the fixing member to the position to face the heat carrier passage via the top panel. Even if the temperature sensor is deviated from the position to face the heat carrier passage via the top panel, the temperature sensor can achieve the exact and quick detection of the temperature of the heat carrier as long as the fixing member constituting the main heat transfer passage is fixed to the position to face the heat carrier passage via the top panel.

[0014] In the heat exchange apparatus according to another aspect of the invention, the temperature sensor support board may be formed with a penetration portion. Further, the fixing member may include: a bracket fixed to the outside surface of the top panel at a position to face the heat carrier passage via the top panel; a shaft member fixed to the bracket and penetrating through the penetration portion formed in the temperature sensor support board; and a pressing member fixed to the shaft member penetrating through the penetration portion and pressing down the temperature sensor support board onto the bracket. Further, the shaft member may be fixed to the outside surface of the top panel at a position to face a central part of the heat carrier passage via the top panel.

[0015] In the heat exchange apparatus according to another aspect of the invention, the bracket may also be fixed to the outside surface of the top panel by brazing. According to the above fixing by brazing, a braze alloy having a low melting point than the top panel and the bracket permits the bracket to be fixed to the top panel without melting the top panel nor the bracket.

[0016] In the heat exchange apparatus according to another aspect of the invention, the top panel may also be flat and thinner than the bottom panel, the bottom panel may also be curved, the heat carrier may also be a liquid coolant, the penetration portion may also be a through-hole, the shaft member may also be a bolt, the pressing member may also be a nut, and the bottom panel may also abut on a wall of a casing.

[0017] If a U-shaped notch, for example, is formed in the temperature sensor support board, the notch permits the shaft member to penetrate therethrough. Hence, the penetration portion formed in the temperature sensor support board need not be the through-hole. However, the penetration portion defined by an enclosed through-hole is easier to handle. What is required of the shaft member fixed to the bracket is that the shaft member is fixed to the bracket as fixing the temperature sensor to place. For example, the shaft member may be a bolt fixedly screwed in a screw hole formed in the bracket. In this case, if the bolt is screwed in the screw hole of the bracket, the head of the bolt serves as the pressing member for pressing down the temperature sensor support board onto the bracket. A structure where the bolt is screwed in the screw hole of the bracket so that the head of the bolt presses down the temperature sensor support board onto the bracket may be adopted. An alternative structure where the temperature sensor support board is pressed down onto the bracket by screwing the nut on the bolt projecting from the bracket may also be adopted.

[0018] According to the heat exchange apparatus disclosed herein, the main heat transfer passage extending from the heat carrier in the heat carrier passage to the temperature sensor is notably reduced in the passage length. This provides for the exact and quick detection of the temperature of the heat carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The features, advantages, and technical and industrial significance of this invention will be described in the following detailed description of example embodiments of the invention with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

[0020] FIG. **1** is a sectional view showing a temperature sensor fixing portion of a heat exchange apparatus according to an embodiment of the invention;

[0021] FIG. **2** is a perspective view showing the temperature sensor fixing portion of the heat exchange apparatus according to the embodiment of the invention;

[0022] FIG. **3** is a sectional view showing a temperature sensor fixing portion of a heat exchange apparatus according to Related Art; and

[0023] FIG. **4** is a perspective view showing the temperature sensor fixing portion of the heat exchange apparatus according to Related Art.

DETAILED DESCRIPTION OF EMBODIMENTS

[0024] The following is a list of main features of an embodiment of the invention to be described hereinbelow.

Feature 1: A semiconductor device which generates heat when operating is disposed on an outside surface of a top panel of a heat exchanger body. A liquid coolant flows through the heat exchanger body. The semiconductor device is cooled with the liquid coolant.

Feature 2: An upper limit of output power from the semiconductor device is set according to the detected temperature of the liquid coolant thereby preventing the overheating of the semiconductor device. If the temperature detection has low accuracy, the upper limit must be set to a lower value because

a substantial margin need be allowed for the upper limit. If the temperature detection is increased in accuracy, the margin allowed for the upper limit can be reduced so that the value of the upper limit can be increased. Increase in the accuracy of temperature detection leads to the expansion of operating range of the semiconductor device.

Feature 3: The semiconductor device regulates electric power supplied to a traction motor. The increase in the operating range of the semiconductor device leads to improvement of the travelling performance of the vehicle.

Feature 4: A wall of a casing accommodating an electronic device which generates heat when operating abuts on a bottom panel of the heat exchanger body.

[0025] FIG. **2** shows, in perspective, the vicinity of a heat carrier inflow pipe **22** of the heat exchanger body **7**. FIG. **1** is a sectional view taken on the line I-I in FIG. **2**. In FIG. **1** and FIG. **2**, a reference numeral **6** denotes a bottom panel; a reference numeral **8** denotes a top panel; a reference numeral **10** denotes a bracket; a reference numeral **12** denotes a bolt; a reference numeral **14** denotes a nut; a reference numeral **16** denotes a temperature sensor support board; a reference numeral **18** denotes a temperature sensor; a reference numeral **20** denotes a cable for transmitting an output from the temperature sensor to an external device. A reference numeral **4** denotes a heat carrier passage. A reference numeral **2** denotes a casing. A semiconductor device which generates heat when operating is fixed to an unillustrated area of an outside surface of the top panel **8** via a board formed of a material which has electrical insulative properties and high heat conductivity. Accommodated in the casing **2** is an electronic device which generates heat when operating. A liquid coolant flows through the heat carrier passage **4**, cooling the semiconductor device in contact with the top panel **8** as well as cooling a wall of the casing **2** in contact with the bottom panel **6**. The top panel **8** and the bottom panel **6** are formed from an aluminum alloy having high heat conductivity. In this embodiment, the heat exchanger body **7** is a cooler body, the heat carrier is the liquid coolant, and the heat carrier passage **4** is a liquid coolant passage. It is to be noted, however, that the fixing structure for the temperature sensor according to the embodiment is not only effective in cooling operation but also effective in heating operation using the heat carrier. Further, the temperature sensor fixing structure of the embodiment is also effective for a case where the heat carrier is gaseous.

[0026] As shown in FIG. **1**, the top panel **8** is flat while the bottom panel **6** is curved. The heat carrier passage **4** is formed by superposing the top panel **8** on the bottom panel **6**, followed by brazing overlapped opposite ends thereof. Overlapped areas of the top panel **8** and the bottom panel **6** are formed with a plurality of through-holes **24**. Bolts **25** penetrating through these through-holes are screwed into the wall of the casing **2** thereby fixing the heat exchanger body **7** to the casing **2**. Fixing the heat exchanger body **7** to the casing **2** brings the bottom panel **6** into intimate contact with the casing **2**. Indicated at **27** in the figure is a sleeve.

[0027] A bracket **10** is brazed to the outside surface of the top panel **18** in order to fix the temperature sensor **18** to the top panel **8**. The bracket **10** is formed with a stepped through-hole **10***a* for receiving a head and a shank of the bolt **12**. The bolt **12** is press-inserted into the through-hole **10***a*. The head of the bolt **12** is brazed to the top panel **8** in conjunction with brazing the bracket **10** to the outside surface of the top panel **8**. The shank of the bolt **12** extends upward from the bracket **10**.

[0028] The temperature sensor **18** is a thermistor and is fixed to the temperature sensor support board **16**. The temperature sensor support board **16** is formed with a through-hole **16***a* which allows the shank of the bolt **12** to penetrate therethrough. After the shank of the bolt **12** is inserted through the through-hole **16***a* of the temperature sensor support board **16**, the nut **14** is screwed on the bolt **12**. When the nut **14** is screwed on the bolt **12**, the nut **14** presses down the temperature sensor support board **16** onto the bracket **10**, thus fixing the temperature sensor support board **16** to the top panel **8**. The bracket **10**, bolt **12** and temperature sensor support board **16** are formed from aluminum alloy having high heat conductivity. When the temperature sensor **18** is fixed to the top panel **8** via the temperature sensor support board **16** by using the bracket **10**, bolt **12** and nut **14**, the temperature sensor **18** is disposed at an area deviated from a position to face the heat carrier passage **4** via the top panel **8**.

[0029] The bracket **10** and the bolt **12** fixed to the bracket **10** are disposed at positions to face the heat carrier passage **4** via the top panel **8**. As shown in FIG. **1**, the bolt **12** is disposed at the position to face a central part of the heat carrier passage **4** via the top panel **8**. Furthermore, the top panel **8** is thinner than the bottom panel **6**. The main heat transfer passage from the heat carrier in the heat carrier passage **4** to the temperature sensor **18** goes from the heat carrier in the heat carrier passage **4**→the top panel **8**→the bolt **12**→the temperature sensor support board **16**→the temperature sensor **18**. The length of the heat transfer passage from the heat carrier in the heat carrier passage **4** to the temperature sensor **18** is minimized. The position of the through-hole **16***a* formed in the temperature sensor support board **16** is deviated from the fixing position of the temperature sensor **18**. Hence, the temperature sensor **18** is deviated from the position to face the heat carrier passage **4** via the top panel **8**. Even so, the temperature sensor **18** involves less detection error and detection delay because the main heat transfer passage is short in length.

[0030] In the case shown in FIG. **3**, the temperature sensor **18** faces the heat carrier passage **4** via the top panel **8**. At first glance, the structure of FIG. **3** is more adapted for the exact and quick detection of the temperature of the heat carrier by means of the temperature sensor **18**. Actually, however, the structure of FIG. **1** is more adapted for the exact and quick detection of the temperature of the heat carrier. The reason is that the temperature sensor **18** of FIG. **1** or the temperature sensor **18** of FIG. **3** is not in intimate contact with the bracket **10** nor the top panel **8** and hence, the amount of heat transmitted to the temperature sensor **18** is low. It was found that what is important is to reduce the length of the heat transfer passage including metal-to-metal intimate contact so as to be capable of transferring a large amount of heat. In the case shown in FIG. **1**, the heat transfer passage from the heat carrier in the heat carrier passage **4** to the temperature sensor support board **16** is minimized in the length and hence, the structure of FIG. **1** is adapted to detect the temperature of the heat carrier more exactly and quickly than the structure of FIG. **3**.

[0031] According to the embodiment, the heat transfer passage going from the heat carrier in the heat carrier passage **4**→the top panel **8**→the bolt **12**→the temperature sensor support board **16**→the temperature sensor **18** is spaced farther away from the wall of the casing **2** than the heat transfer passage shown in FIG. **3**. Therefore, the influence that the heat of the wall of the casing **2** exerts on the temperature sensor **18** is reduced. With the additional effect of the reduced

influence of the heat of the wall, the structure of the embodiment is adapted for the exact and quick detection of the temperature of the heat carrier by means of the temperature sensor **18**.

[0032] In the above-described embodiment, the temperature sensor support board **16** is pressed down onto the bracket **10** by screwing the nut **14** on the bolt **12** anchored in the bracket **10**. Alternatively, a screw hole may be formed in the bracket **10** and the bolt may be screwed into the screw hole so as to permit the head of the bolt to press down the temperature sensor support board **16** onto the bracket **10**. A shaft member fixed in the bracket may be the shank of the bolt **12** anchored in the bracket **10** or the shank of the bolt screwed into the bracket **10**. A pressing member for pressing down the temperature sensor support board **16** on the bracket **10** may be the nut **14** or the head of the bolt. The combination of bolt and nut may be replaced by a rivet drivenly fixed in the bracket **10**. The temperature sensor support board **16** can be pressed down onto the bracket **10** with a head of the rivet. The shaft member may be formed integrally with the bracket.

[0033] Although the specific examples of the invention have been described in detail, these examples are intended for purposes of illustration only and are not intended to limit the scope of the appended claims. The techniques disclosed in the scope of the claims include various modifications and changes of the above examples. Further, the technical elements described in this specification or shown in the drawings deliver technical utilities as used alone or in various combinations thereof and hence, are not limited to the combinations stated in the claims of this patent application. The techniques illustrated in this specification or the drawings are intended to achieve a plurality of purposes at a time and hence, deliver the technical utility by achieving any one of these purposes.

What is claimed is:

1. A heat exchange apparatus comprising:

a main body that includes a top panel and a bottom panel, the top panel superposed on top of the bottom panel to define a heat carrier passage therebetween;

a temperature sensor that is fixed to a temperature sensor support board; and

a fixing member that fixes the temperature sensor support board to the top panel and is fixed to an outside surface of the top panel at a position to face the heat carrier passage via the top panel.

2. The heat exchange apparatus according to claim **1**, wherein

the temperature sensor is disposed at place deviated from a position to face the heat carrier passage via the top panel.

3. The heat exchange apparatus according to claim **1**, wherein

the temperature sensor support board is formed with a penetration portion, and the fixing member includes: a bracket fixed to the outside surface of the top panel at a position to face the heat carrier passage via the top panel; a shaft member fixed to the bracket and penetrating through the penetration portion; and a pressing member fixed to the shaft member penetrating through the penetration portion and pressing down the temperature sensor support board onto the bracket.

4. The heat exchange apparatus according to claim **1**, wherein

the shaft member is fixed to the outside surface of the top panel at a position to face a central part of the heat carrier passage via the top panel.

5. The heat exchange apparatus according to claim **3**, wherein

the bracket is fixed to the outside surface of the top panel by brazing.

6. The heat exchange apparatus according to claim **1**, wherein

the top panel is flat and thinner than the bottom panel, the bottom panel is curved, the heat carrier is a liquid coolant, the penetration portion is a through-hole, the shaft member is a bolt, the pressing member is a nut, and the bottom panel abuts on a wall of a casing accommodating an object with which heat is exchanged.

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