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LIQUID LEVEL DETECTION DEVICE

Abstract

The liquid level detection device includes a temperature sensor disposed at a predetermined position in a tank for storing liquid hydrogen, a heater capable of raising an ambient temperature at the predetermined position, a liquid level detection unit for detecting whether the liquid level of the liquid hydrogen in the tank has reached the predetermined position based on a change in a temperature detected by the temperature sensor, and a heater state determination unit for determining whether an abnormality is caused in the state of the heater. The heater state determination unit is configured to be capable of executing a temperature raising process for raising the ambient temperature, and a determination process for determining that the state of the heater is abnormal when an increase exceeding a predetermined temperature range does not occur in the detected temperature within a predetermined time after the temperature raising process is started.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-019705 filed on Feb. 13, 2024, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

[0002] The technique disclosed herein relates to a technique of detecting a liquid level of liquid hydrogen stored in a tank.

2. Description of Related Art

[0003] When liquid hydrogen is filled in a tank for storing liquid hydrogen, it is necessary to detect that a predetermined amount of liquid hydrogen has accumulated. Japanese Unexamined Patent Application Publication No. 2014-98659 (JP 2014-98659 A) discloses, as a related art, a technique of measuring a liquid level of liquid hydrogen stored in a heat insulating container using a liquid hydrogen level sensor.

SUMMARY

[0004] A sensor disposed in a tank detects the liquid level of the liquid hydrogen in the tank based on a temperature change caused by a liquid surface touching the sensor. In order to improve the accuracy of such detection, a heater that increases the ambient temperature is provided in the tank. However, it is not determined whether the state of the heater is normal or abnormal. A reliable detection result cannot be obtained if liquid level detection is executed while it is unknown whether the heater is abnormal.

[0005] An aspect of the present specification discloses a liquid level detection device. [0006] The liquid level detection device includes: [0007] a temperature sensor disposed at a predetermined position in a tank that stores liquid hydrogen; [0008] a heater capable of raising an ambient temperature at the predetermined position in the tank; [0009] a liquid level detection unit that detects whether a liquid level of the liquid hydrogen in the tank has reached the predetermined position based on a change in a temperature detected by the temperature sensor; and [0010] a heater state determination unit that determines whether a state of the heater is abnormal. The heater state determination unit is configured to be able to execute: [0011] a temperature increasing process of increasing the ambient temperature using the heater; and [0012] a determination process of determining that the state of the heater is abnormal when the detected temperature is not increased by more than a predetermined temperature range within a predetermined time after the temperature increasing process is started.

[0013] According to the above configuration, the heater state determination unit of the liquid level detection device determines that the state of the heater is abnormal when the detected temperature is not increased by more than a predetermined temperature range within a predetermined time after the temperature increasing process is started. Thus, the liquid level detection device can recognize an abnormality of the heater.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which

like signs denote like elements, and wherein:
[0015] FIG. **1** is a diagram schematically illustrating a configuration including a liquid level detection device;
[0016] FIG. **2** is a flow chart showing a process executed by ECU; and
[0017] FIG. **3** is a graph illustrating a change in a temperature detected by a temperature sensor.
DETAILED DESCRIPTION OF EMBODIMENTS
[0018] Embodiments will be described with reference to the drawings. Each of the drawings is merely an example, and the present embodiment is not limited to the illustrated contents. In addition, since each of the drawings is an example, the illustrated shape is not accurate or a part thereof is omitted.
[0019] FIG. **1** schematically illustrates a configuration including a liquid level detection device **10** according to the present embodiment. The liquid level detection device **10** and the tank **20** are mounted on, for example, a vehicle **1** that can travel using hydrogen as a fuel. The tank **20** is a tank for storing the liquid hydrogen **22**, and has a structure of a vacuum double shell. A vehicle traveling by a fuel cell, a vehicle traveling by a hydrogen engine, or the like corresponds to the vehicle **1**. However, the liquid level detection device **10** and the tank **20** may be not only mounted on a moving unit such as the vehicle **1**, but also may be a part of equipment installed in various places. The liquid hydrogen **22** is supplied to the tank **20** from an external hydrogen supply facility **2**.
[0020] The liquid level detection device **10** includes a sensor unit **30** disposed in the tank **20**, an ECU **40** as a control unit, and a power supply **50**. The tank **20** may be included in a part of the liquid level detection device **10** to be interpreted. ECU is an abbreviation for Electronic Control Unit. ECU **40** is one of various ECU mounted on the vehicle **1**. The sensor unit **30** includes, for example, a temperature sensor **32** and a heater **34** held by a holding member **36** such as a predetermined bracket or casing.
[0021] The temperature sensor **32** is a means for detecting the temperature, and is, for example, a thermocouple. The temperature sensor **32** is disposed at a “predetermined position” in the tank **20**. In the present embodiment, this predetermined position is also regarded as an example of the filling completion position of the liquid hydrogen **22**. That is, when the liquid level **24** of the liquid hydrogen **22** reaches a predetermined position where the temperature sensor **32** is disposed, the filling of the liquid hydrogen **22** into the tank **20** is completed, and the tank **20** becomes full.
[0022] When a current is supplied from the power supply **50** to the heater **34** via the resistor **51**, the heater **34** generates heat. In addition, the amount of heat generated by the heater **34** varies according to the amount of current supplied to the heater **34**. The heater **34** is capable of raising the ambient temperature at a predetermined position in the tank **20**. “Increasing the ambient temperature at a predetermined position” does not mean that only the temperature at the predetermined position is increased, but also means that the temperature in the range including the temperature sensor **32** disposed at the predetermined position and the gas in the vicinity of the temperature sensor **32** is increased. The detected temperature detected by the temperature sensor **32** is outputted to ECU **40**.
[0023] ECU **40** includes functional units such as a liquid level detection unit **42**, a heater state determination unit **44**, and an abnormality notification unit **46**. The liquid level detection unit **42** can detect whether the liquid level **24** of the liquid hydrogen **22** in the tank **20** has reached a predetermined position based on a change in the temperature detected by the temperature sensor **32**. The liquefaction temperature of the hydrogen is about −253° C. (20 K). Therefore, the liquid level detection unit **42** compares the detected temperature with a predetermined threshold value (first threshold value) set in the vicinity of the liquefied temperature. Then, the liquid level detection unit **42** detects a state in which the liquid hydrogen **22** is not in contact with the temperature sensor **32** when the detected temperature exceeds the first threshold value, that is, detects a state in which the liquid level **24** does not reach the predetermined position. The liquid level detection unit **42** detects a state in which the liquid level **24** reaches a predetermined position

when the detected temperature is lower than the first threshold value.

[0024] However, in the tank **20**, the vicinity of the liquid level **24** may be cooled to an air temperature close to the liquefaction temperature. In addition, a part of the liquid hydrogen **22** may temporarily adhere to the temperature sensor **32** due to the swing of the liquid level **24**. For these reasons, it may not be possible to accurately detect whether the liquid level **24** has reached a predetermined position. From this point of view, a heater **34** is provided. That is, in a situation where the liquid level **24** does not reach the temperature sensor **32**, the temperature detected by the temperature sensor **32** surely exceeds the first threshold value due to the temperature raising effect by the heater **34**. However, it is assumed that the heater **34** operates normally. If there is an abnormality in the heater **34**, the detection result by the liquid level detection unit **42** based on the temperature detected by the temperature sensor **32** becomes unreliable. Therefore, in the present embodiment, as described below, the heater state determination unit **44** determines whether the state of the heater **34** is abnormal.

[0025] FIG. **2** is a flow chart illustrating a process executed by ECU **40** in the present embodiment. When ECU **40** recognizes that the supply of the liquid hydrogen **22** from the hydrogen supply facility **2** to the tank **20** is started, the flow chart starts.

[0026] In S**100**, the heater state determination unit **44** acquires the detected temperature from the temperature sensor **32**. The detected temperature acquired by S**100** is referred to as an early detected temperature. Then, in S**110**, the heater state determination unit **44** determines whether the initially detected temperature exceeds the first threshold. The heater state determination unit **44** proceeds from the determination of “Yes” of S**110** to S**120** when the initial detected temperature exceeds the first threshold, and proceeds from the determination of “No” of S**110** to S**190** when the initial detected temperature falls below the first threshold.

[0027] When the initial detected temperature is lower than the first threshold, the heater state determination unit **44** assumes that the liquid level **24** is in contact with the temperature sensor **32**, and proceeds to S**190** without executing a determination process described later. In S**110** and $**150**, S**180** to be described later, the values to be compared rarely coincide with each other, but in such cases, the flow chart may be designed to branch to either “Yes” or “No”.

[0028] In S**120**, the heater state determination unit **44** outputs an operation instruction of the heater **34** to the power supply **50**, and causes the power supply **50** to operate the heater **34**. The heater state determination unit **44** starts a temperature raising process of raising the ambient temperature at a predetermined position to the heater **34** by S**120**. Note that S**120** timing is not limited to the timing after S**110**, and may be, for example, the timing after S**100** and before S**110**, or may be the timing in parallel with S**110**.

[0029] The heater state determination unit **44** acquires the detected temperature from the temperature sensor **32** at a timing when a predetermined time has elapsed from S**120** (S**130**). Here, the predetermined time is, for example, about 10 seconds. In S**140**, the heater state determination unit **44** calculates a difference (increased temperature range) obtained by subtracting the initial-detected temperature from the detected temperature acquired by S**130**.

[0030] In S**150**, the heater state determination unit **44** determines whether the rising temperature range exceeds a predetermined temperature range. The heater state determination unit **44** proceeds from the determination of “Yes” of S**150** to S**160** when the rising temperature range exceeds the predetermined temperature range, and proceeds from the determination of “No” of S**150** to S**200** when the rising temperature range does not exceed the predetermined temperature range. Since the rising temperature range is assumed to be a positive value, the predetermined temperature range is also a positive value. If the temperature-rise range is negative, the determination of S**150** is naturally “No”.

[0031] In S**160**, the heater state determination unit **44** determines that the state of the heater **34** is normal, and proceeds to S**170**. On the other hand, in S**200**, the heater state determination unit **44** determines that the state of the heater **34** is abnormal because the temperature increase by the heater **34** is insufficient, and proceeds to S**210**. S**130**, S**140**, S**150**, S**160**, S**200** corresponds to an exemplary determination process. According to such determination processing, the heater state determination unit **44** determines that the state of the heater **34** is abnormal when an increase in the temperature detected by the temperature sensor **32** that exceeds the predetermined temperature range does not occur within a predetermined time after the start of the temperature increase processing.

[0032] Note that the heater state determination unit **44** may compare the rising temperature range with the predetermined temperature range not only at the timing (the timing of S**130**) at which the predetermined time has elapsed since S**120**, but also at one or more times, for example, every second, even prior to the lapse of the predetermined time. That is, during the period from S**120** until the predetermined time elapses, the difference (increase temperature range) between the latest detected temperature acquired from the temperature sensor **32** at that time point and the initial detected temperature is calculated and compared with the predetermined temperature range. If the current temperature rise range is greater than the predetermined temperature range, the process may proceed to S**160** prior to the elapse of the predetermined period.

[0033] The state leading to S**170** corresponds to a case where the temperature detected by the temperature sensor **32** exceeds the first threshold value and the state of the heater **34** is not determined to be abnormal by the heater state determination unit **44**. In S**170**, the liquid level detection unit **42** acquires the detected temperature from the temperature sensor **32**. Then, in S**180**, the liquid level detection unit **42** determines whether the detected temperature obtained by S**170** exceeds the first threshold.

[0034] The liquid level detection unit **42** returns to S**170** from the determination of S**180** “No” to S**190** when the detected temperature acquired by S**170** is lower than the first threshold, and from the determination of S**180** “Yes” when the detected temperature acquired by S**170** is higher than the first threshold. That is, the liquid level detection unit **42** repeats S**170**, S**180** until it can be determined as “No” by S**180**. Such a S**170**, S**180** corresponds to a process for detecting the liquid level **24**.

[0035] In S**190**, the liquid level detection unit **42** detects that the liquid level **24** has reached the predetermined position, and the flow chart ends. When the flow chart is completed by S**190**, ECU **40** can, of course, stop supplying the liquid hydrogen **22**. The specific method for stopping the supply of the liquid hydrogen **22** is not particularly limited. For example, ECU **40** instructs the hydrogen supply facility **2** to stop the supply of the liquid hydrogen **22** by wired or wireless communication with the hydrogen supply facility **2**.

[0036] In S**210**, the abnormality notification unit **46** notifies the outside of the abnormality of the heater **34**, and then ends the flow chart. The outside is not particularly limited, but is, for example, the hydrogen supply facility **2**. The hydrogen supply facility **2** can stop the supply of the liquid hydrogen **22** to the tank **20** when a notification of an abnormality of the heater **34** is received from the abnormality notification unit **46**. In addition, when receiving the notification of the abnormality of the heater **34**, the hydrogen supply facility **2** may display, for example, a message indicating that an abnormality has occurred in the heater **34**, a message indicating that the liquid level **24** in the tank **20** cannot be accurately detected, a message indicating that the supply of the liquid hydrogen **22** has been stopped, and the like on the display panel **3** or the like included in the hydrogen supply facility **2** to notify the user. The outside as the notification destination by the abnormality notification unit **46** may include not only the hydrogen supply facility **2** but also a terminal such as a computer or a smartphone registered in advance in the abnormality notification unit **46**.

[0037] FIG. **3** graphically illustrates the change in the detected temperature F with respect to time by the temperature sensor **32**. The temperature E**0** corresponds to a first threshold. A specific example according to the above-described flowchart will be described with reference to FIG. **3**. It is assumed that the detected temperature F as the initial detection temperature is a temperature E**1** higher than the temperature E**0** (S**110** “Yes”), and the temperature raising process is started at the time T**1** (S**120**). When the rise temperature range of the detected temperature F from the initial detection temperature at the time T**2** at which the predetermined time has elapsed from the time T**1** exceeds the predetermined temperature range G (S**150** “Yes”), the heater state determination unit **44** determines that the state of the heater **34** is normal (S**160**). After that, the detected temperature F continues to increase due to the temperature raising effect by the heater **34**, but when the position of the liquid level **24** rises and touches the temperature sensor **32**, the detected temperature F rapidly decreases. When the detected temperature F falls below the temperature E**0** (S**180** “No”), the liquid level detection unit **42** detects that the liquid level **24** has reached the predetermined position (S**190**).

[0038] On the other hand, after the start (S**120**) of the temperature raising process in the time T**1**, for example, when the change in the detected temperature F takes a behavior such as a temperature E**2** indicated by a two-dot chain line, the temperature rise range from the initial detected temperature does not exceed the predetermined temperature range G at the time T**2** (S**150** “No”) (temperature rise range=temperature E**2**−temperature E**1**). Then, the heater state determination unit **44** determines that the state of the heater **34** is abnormal (S**200**).

[0039] As described above, according to the present embodiment, the liquid level detection device **10** includes the temperature sensor **32** disposed at a predetermined position in the tank **20** that stores the liquid hydrogen **22**, the heater **34** capable of raising the ambient temperature at the predetermined position in the tank **20**, the liquid level detection unit **42** that detects whether or not the liquid level **24** of the liquid hydrogen **22** in the tank **20** has reached the predetermined position based on the change in the detected temperature by the temperature sensor **32**, and the heater state determination unit **44** that determines whether or not the state of the heater **34** is abnormal. The heater state determination unit **44** is configured to execute a temperature raising process of raising the ambient temperature by the heater **34**, and a determination process of determining that the state of the heater **34** is abnormal when an increase exceeding a predetermined temperature range does not occur in the detected temperature within a predetermined time after the start of the temperature raising process. According to the above configuration, the liquid level detection device **10** can recognize the abnormality when the abnormality occurs in the heater **34**. Therefore, the liquid level detection device **10** can also avoid detecting whether the liquid level **24** has reached the predetermined position in an abnormal state of the heater **34**.

[0040] Further, according to the present embodiment, in the determination process, the heater state determination unit **44** may determine whether or not an increase in the detected temperature exceeding the predetermined temperature range has occurred at least at a timing when the predetermined time has elapsed from the start of the temperature increase process.

[0041] According to the above configuration, the heater state determination unit **44** can determine the presence or absence of the abnormality with a small processing amount by executing, at the timing, a determination as to whether an increase in the detected temperature exceeding the predetermined temperature range has occurred.

[0042] In addition, according to the present embodiment, the heater state determination unit **44** may not execute the determination process when the detected temperature falls below a predetermined threshold value (first threshold value). [0043] According to the above configuration, the heater state determination unit **44** can prevent the useless processing from being performed when the detected temperature is lower than the first threshold value and thus there is substantially no meaning of executing the determination processing.

[0044] In addition, according to the present embodiment, the liquid level detection unit **42** may start a process for detecting the liquid level **24** when the detected temperature exceeds the first threshold value and the heater state determination unit **44** does not determine that the state of the heater **34** is abnormal.

[0045] According to the above configuration, the liquid level detection unit **42** has a premise for detecting the liquid level **24**, and after confirming that there is no abnormality in the heater **34**, by starting the process for detecting the liquid level **24**, thereafter, it is possible to accurately detect the liquid level **24**.

[0046] In addition, according to the present embodiment, the liquid level detection device **10** may further include an abnormality notification unit **46** that notifies the outside of the abnormality when the heater state determination unit **44** determines that the state of the heater **34** is abnormal. [0047] According to the above configuration, the liquid level detection device **10** can notify the outside that the state of the heater **34** is abnormal.

[0048] While specific examples of the technology disclosed herein have been described in detail above, these are merely illustrative and do not limit the scope of the claims. Various modifications and variations of the specific examples described above are included in the technology described in the claims. In addition, the technical elements described in the present specification or the drawings exhibit technical usefulness alone or in various combinations, and are not limited to the combinations described in the claims at the time of filing. Further, the technology illustrated in the present specification or the drawings achieves a plurality of objects at the same time, and has technical usefulness by achieving one of the objects.

Claims

1. A liquid level detection device comprising: a temperature sensor disposed at a predetermined position in a tank that stores liquid hydrogen; a heater capable of raising an ambient temperature at the predetermined position in the tank; a liquid level detection unit that detects whether a liquid level of the liquid hydrogen in the tank has reached the predetermined position based on a change in a temperature detected by the temperature sensor; and a heater state determination unit that determines whether a state of the heater is abnormal, wherein the heater state determination unit is configured to be able to execute: a temperature increasing process of increasing the ambient temperature using the heater; and a determination process of determining that the state of the heater is abnormal when the detected temperature is not increased by more than a predetermined temperature range within a predetermined time after the temperature increasing process is started.

2. The liquid level detection device according to claim 1, wherein the heater state determination unit determines in the determination process whether the detected temperature is increased by more than the predetermined temperature range at least at a timing when the predetermined time has elapsed since the temperature increasing process is started.

3. The liquid level detection device according to claim 1, wherein the heater state determination unit does not execute the determination process when the detected temperature falls below a predetermined threshold value.

4. The liquid level detection device according to claim 3, wherein the liquid level detection unit starts a process of detecting the liquid level when the detected temperature exceeds the threshold value and the heater state determination unit does not determine that the state of the heater is abnormal.

5. The liquid level detection device according to claim 1, further comprising an abnormality notification unit that notifies an outside of an abnormality when the heater state determination unit determines that the state of the heater is abnormal.