

CRYOGENIC CALIBRATION SYSTEM FOR LIQUID FLOWMETERS AND OPERATING METHOD THEREOF

【TECHNICAL FIELD】

[0001] The present invention relates to a liquid flowmeter, which is an instrument for measuring the flow rate of liquefied gas in a cryogenic environment, and more particularly, to a system for securing measurement traceability in calibration of a liquid flowmeter that measures a flow rate of a liquefied gas in a cryogenic environment, and a method of operating the same.

【BACKGROUND ART】

[0003] A flowmeter is an instrument for measuring the flow rate of liquid or gas conveyed through a pipeline, and is classified as either a liquid flowmeter or a gas flowmeter depending on the type of fluid. Such flowmeters are used to measure flow rates in a wide range of industrial fields, including water resources and wastewater treatment, heavy chemical industries, food and beverages, and the semiconductor industry.

[0004] In accordance with the global trend toward eco-friendliness, the roles of LNG, liquid hydrogen, and similar substances are being increasingly emphasized, and accordingly, the need to calibrate liquid flowmeters in cryogenic environments has become more prominent.

[0005] Among the methods for calibrating liquid flowmeters, the gravimetric method—which collects a steadily flowing fluid over a specified period of time and then measures the collected weight—is known as the most accurate method.

[0006] As an effort to calibrate liquid flowmeters in cryogenic environments, the United States NBS (predecessor to NIST) designed and established a Cryogenic Flow Facility in the 1970s, which was operated until 2015. This facility was

transferred to CEESI, a calibration specialist company, in 2016, and was decommissioned around 2020 after joint research was conducted. Meanwhile, VSL in the Netherlands established a cryogenic Primary Standard Loop (PSL) and Mid-Scale Loop (MSL) for LNG calibration.

[0007] However, in South Korea, research on methods for calibrating liquid flowmeters in cryogenic environments is significantly lacking, and the associated facilities are also insufficient. Therefore, technology and facilities for calibrating liquid flowmeters—which measure the flow rate of liquefied gases whose demand is rapidly increasing—in cryogenic environments are urgently needed.

[0008] Furthermore, in one of the existing methods for calibrating liquid flowmeters in cryogenic environments (such as the Dutch VSL system), it was difficult to calibrate liquid flowmeters within a small margin of error because the temperature inside the calibration system increased or the pressure dropped, causing the liquefied gas to enter a gas-liquid two-phase flow state.

【DETAILED DESCRIPTION OF THE INVENTION】

【TECHNICAL PROBLEM】

[0010] An object of the present invention, devised to solve the above problems, is to provide a calibration system and an operating method thereof for calibrating a liquid flowmeter that measures the flow rate of liquefied gas in a cryogenic environment within a small margin of error.

[0011] Another object of the present invention is to continuously calibrate liquid flowmeters without interrupting the calibration system, thereby reducing the time required for calibration and preventing unnecessary energy waste during restart.

[0012] Another object of the present invention is to provide calibration system components having a double insulation structure or vacuum structure that are less

susceptible to external heat, so as to prevent the vaporization of liquefied gas that occurs when the temperature inside the components rises due to external heat.

[0013] Another object of the present invention is to cool the inside of the calibration system prior to calibration and maintain it below a certain temperature, thereby preventing liquefied gas from vaporizing due to a rise in the internal temperature of the calibration system.

[0014] Another object of the present invention is to increase the pressure of the calibration system prior to calibration and maintain it above a certain pressure, thereby preventing liquefied gas from vaporizing due to a drop in the internal pressure of the calibration system.

[0015] Another object of the present invention is to provide a calibration system environment identical to the actual operating environment of liquefied gas.

[0016] Another object of the present invention is to reuse the liquefied gas that has been used, in order to reduce environmental pollution caused by the discharge of liquefied gas to the outside.

[0017] The technical problems to be achieved by the present invention are not limited to the technical problems mentioned above, and other technical problems not mentioned will be clearly understood by those skilled in the art to which the present invention belongs from the description below.

【SOLUTION TO PROBLEM】

[0019] In order to achieve the above objects, the configuration of the present invention comprises:

a storage tank for storing liquefied gas; a vaporizer having one end connected to the storage tank and the other end connected to a heat exchanger, which vaporizes the liquefied gas supplied from the storage tank; a heat exchanger having one end connected to the storage tank and the other end connected to a measurement tank,

which cools the liquefied gas supplied from a circulation tank using the liquefied gas supplied from the storage tank and supplies the cooled liquefied gas to the measurement tank; a measurement tank having one end connected to the heat exchanger and the other end connected to a circulation tank, which measures the weight of the liquefied gas supplied from the heat exchanger through a scale provided at its lower end; a circulation tank having one end connected to the measurement tank and the other end connected to a circulation pump, which receives the liquefied gas after measurement is completed in the measurement tank; a circulation pump having one end connected to the circulation tank and the other end connected to the heat exchanger, which supplies the liquefied gas stored in the circulation tank to the heat exchanger; and a flow path switching valve that blocks the supply of liquefied gas from the measurement tank to the circulation tank and changes the flow path of the liquefied gas so that the liquefied gas is stored in the measurement tank, wherein the weight value of the liquefied gas stored in the measurement tank for a period of time is measured by the scale, and the flow rate value of the liquid flowmeter is calibrated based on the measured weight value.

[0020] In an embodiment of the present invention, the flow path switching valve may be a solenoid valve.

[0021] In another embodiment, the measurement tank may be manufactured as a double-walled vessel, and a vacuum may be formed between the outer and inner vessels constituting the double-walled vessel.

[0022] Furthermore, the storage tank, vaporizer, heat exchanger, measurement tank, circulation tank, and circulation pump may be connected to each other by pipelines, wherein the pipelines are configured as inner and outer double pipelines, and a vacuum is formed between the double pipelines.

【ADVANTAGEOUS EFFECTS OF THE INVENTION】

[0024] The effects of the present invention based on the above configuration are as follows: liquid flowmeters can be calibrated within a small margin of error in a cryogenic environment.

[0025] According to the present invention, liquid flowmeters can be calibrated continuously, which reduces the time required for calibration and prevents unnecessary energy waste for restarting.

[0026] Since the components constituting the calibration system have a double insulation structure or vacuum structure, they are less affected by external heat, allowing the calibration system to be maintained at a constant low temperature. This prevents the vaporization of liquefied gas caused by a rise in the internal temperature of the calibration system due to external heat, thereby reducing calibration error and improving precision.

[0027] A cooling operation step is provided to cool the inside of the calibration system and maintain it below a certain temperature prior to calibration, thereby preventing the vaporization of liquefied gas caused by a rise in the internal temperature of the calibration system, reducing calibration error, and improving precision.

[0028] A pressure control operation step is provided to increase the internal pressure of the calibration system and maintain it above a certain pressure prior to calibration, thereby preventing the vaporization of liquefied gas caused by a drop in the internal pressure of the calibration system, reducing calibration error, and improving precision.

[0029] The calibration system provides a system environment identical to the actual operating environment of liquefied gas, thereby reducing calibration error and improving precision.

[0030] The used liquefied gas can be reused, thereby reducing environmental

pollution caused by its discharge to the outside.

[0031] The effects of the present invention are not limited to the effects described above, and should be understood to include all effects that can be inferred from the configurations of the invention described in the detailed description or claims of the present invention.

【BRIEF DESCRIPTION OF THE DRAWINGS】

[0033] FIG. 1 is an exemplary diagram of a cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

[0034] FIG. 2 is a schematic diagram of a cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

[0035] FIG. 3 is a schematic diagram showing a cooling operation state of the cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

[0036] FIG. 4 is a schematic diagram showing a pressure control operation state of the cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

[0037] FIG. 5 is a schematic diagram showing a circulation operation state of the cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

[0038] FIG. 6 is a schematic diagram showing a calibration operation state of the cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

【BEST MODE】

[0040] The most preferred embodiment of the present invention relates to a system for securing measurement traceability in calibration of a liquid flowmeter

that measures a flow rate of a liquefied gas in a cryogenic environment, and a method of operating the same.

【DESCRIPTION OF EMBODIMENTS】

[0042] Hereinafter, the present invention will be described in detail with reference to the accompanying drawings. However, the present invention may be embodied in various different forms and is therefore not limited to the embodiments described herein. In the drawings, parts irrelevant to the description have been omitted for clarity of illustration of the present invention, and like reference numerals designate like parts throughout the specification.

[0043] Throughout the specification, when an element is referred to as being “connected with (coupled to, combined with, in contact with)” another element, it may be “directly connected” to the other element and may also be “indirectly connected” to the other element with another element intervening therebetween. Further, unless explicitly described otherwise, “comprising” any components will be understood to imply the inclusion of other components rather than the exclusion of any other components.

[0044] Terms used in the present invention are used only in order to describe specific exemplary examples rather than limiting the present invention. Singular expressions are intended to include plural forms unless the context clearly indicates otherwise. It will be further understood that the terms “comprise” or “have” used in this specification specify the presence of stated features, numerals, steps, operations, components, parts, or a combination thereof, but do not preclude the presence or addition of one or more other features, numerals, steps, operations, components, parts, or a combination thereof.

[0045] In addition, terms such as ‘~er’, ‘~unit’, ‘~module’, etc. used herein mean the units for processing at least one function or operation and may be

implemented by hardware, software, or a combination of hardware and software.

[0046] Furthermore, in the specification, when a step is positioned “before” or “after” another step, this includes the same right as not only when the step and another step are in a direct time-serial relationship, but when they are in an indirect time-serial relationship in which the orders of the two steps may be time-serially changed such as mixing of the steps after the steps.

[0047] Hereinafter, examples of the present invention are described in detail with reference to the accompanying drawings. In the following detailed description, liquid nitrogen (-196°C) is used as an example for convenience in describing the cryogenic calibration system for liquid flowmeters and the operating method thereof; however, the cryogenic calibration system for liquid flowmeters of the present invention may also be used to calibrate liquid flowmeters for liquefied gases such as liquefied natural gas (LNG, -162°C), liquid methane (-163°C), liquid oxygen (-183°C), liquid hydrogen (-253°C), and liquid helium (-269°C).

[0048] FIG. 1 is an exemplary diagram of the cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention, and FIG. 2 is a schematic diagram thereof.

[0049] Referring to FIGS. 1 and 2, a storage tank (10) is disposed outside the cryogenic calibration system for liquid flowmeters (1), and a heat exchanger (30), a circulation pump (40), a circulation tank (50), a measurement tank (60), a scale (70), a first flowmeter (80), a second flowmeter (90), a third flowmeter (100), and a fourth flowmeter (110) are disposed inside the cryogenic calibration system for liquid flowmeters (1).

[0050] A pipeline (p1) formed at one end of the storage tank (10) branches, with one of the branched pipelines (p2) connected to the heat exchanger (30) and the other branched pipeline (p3) connected to the circulation tank (50). The pipeline

(p2) formed at one end of the heat exchanger (30) is connected to the storage tank (10), and the pipeline (p4) formed at the other end of the heat exchanger (30) is connected to the first flowmeter (80) and the second flowmeter (90) and then to the measurement tank (60). The pipeline (p4) formed at one end of the measurement tank (60) is connected to the second flowmeter (90), and the pipeline (p5) formed at the other end of the measurement tank (60) is connected to the circulation tank (50). The pipeline (p3) formed at one end of the circulation tank (50) is connected to the storage tank (10), and the pipeline (p6) formed at the other end of the circulation tank (50) is connected to the circulation pump (40) and then to the heat exchanger (30).

[0051] Liquid nitrogen is stored in the storage tank (10). Liquid nitrogen supplied from the storage tank (10) is either directly supplied to the heat exchanger (30) for cooling, or supplied to the circulation tank (50) and then to the heat exchanger (30) for cooling. Liquid nitrogen supplied to the circulation tank (50) is supplied to the heat exchanger (30) via the circulation pump (40), and the supplied liquid nitrogen is cooled through the heat exchanger (30).

[0052] The low-temperature liquid nitrogen that has passed through the heat exchanger (30) is supplied to the measurement tank (60) via the first flowmeter (80) and the second flowmeter (90). The measurement tank (60) stores the liquid nitrogen supplied for a period of time and measures the weight of the stored liquid nitrogen through the scale (70) provided in the measurement tank (60). After measurement is completed in the measurement tank (60), the liquid nitrogen is supplied to the circulation tank (50) for the next test.

[0053] The circulation tank (50) is made of a material capable of storing ultra-low temperature liquid nitrogen, and is designed with a structure that can maintain airtightness and expansion/contraction in an ultra-low temperature (-196°C) and high-pressure (1.0 MPa) environment. In addition, insulation material is used

in the circulation tank (50) to reduce the amount of heat penetrating the system during operation and to maintain liquid nitrogen in an ultra-low temperature state.

[0054] The measurement tank (60) is manufactured as a double-walled vessel consisting of an inner vessel that stores cryogenic liquid nitrogen and an outer vessel exposed to room temperature. A vacuum is formed between the inner and outer vessels to block heat transfer by convection from the outside. The degree of vacuum formed between the double-walled vessels is preferably 10^{-4} Torr, but may vary depending on the operating conditions of the system.

[0055] The pipelines used to connect the components in the system are made with a double insulation structure. The pipelines consist of inner and outer double pipes, with a vacuum formed between the double pipes. In addition, insulation material is used between the double pipes. As a result, the pipelines are insulated and liquid nitrogen is prevented from vaporizing when supplied into the pipelines.

[0056] The main components constituting the cryogenic calibration system for liquid flowmeters (1) and the interconnections between these components have been described above in general terms, and the operating method of the cryogenic calibration system for liquid flowmeters (1) will be described in greater detail below.

[0057] The operating method of the cryogenic calibration system for liquid flowmeters (1) comprises four steps. Among the four steps, the first step is a cooling operation step, the second step is a pressure control operation step, the third step is a circulation operation step, and the fourth step is a calibration operation step.

[0058] In the cooling operation step, the liquid nitrogen under test is maintained in a subcooling state below the saturation temperature to prevent the liquid nitrogen from vaporizing and entering a gas-liquid two-phase flow state.

[0059] In the pressure control operation step, gaseous nitrogen produced through the vaporizer (20) installed outdoors is cooled through the heat exchanger (30) and then supplied to the measurement tank (60) and the circulation tank (50), thereby pressurizing the inside of the cryogenic calibration system for liquid flowmeters (1) to increase the internal pressure.

[0060] In the circulation operation step, prior to the calibration operation, the system is stabilized so that liquid nitrogen supplied from the outdoor storage tank (10) can stably circulate inside the system at a constant temperature and pressure.

[0061] In the calibration operation step, when the liquid nitrogen circulating inside the cryogenic calibration system for liquid flowmeters (1) reaches a flow-stabilized state, the flow path of the liquid nitrogen is switched to supply the liquid nitrogen to the measurement tank (60). When the liquid nitrogen supplied to the measurement tank (60) has been stored for a predetermined period of time, the weight value of the stored liquid nitrogen is measured by the scale (70) provided at the lower end of the measurement tank (60), and the liquid flowmeter requiring calibration is calibrated accordingly.

[0062] FIG. 3 is a schematic diagram showing a cooling operation state of the cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

[0063] When liquid nitrogen is moved and stored inside the system to measure its weight, if the internal temperature of the system rises and the liquid nitrogen vaporizes into a gas-liquid two-phase flow state, an error occurs when measuring the weight of the liquid nitrogen, making it impossible to calibrate the liquid flowmeter more accurately. Therefore, the inside of the system must be cooled and maintained below a certain temperature to prevent liquid nitrogen from vaporizing, and for this purpose, a cooling operation to cool the inside of the system is essential.

[0064] Referring to FIG. 3, the liquid nitrogen stored in the storage tank (10) is supplied to the heat exchanger (30) and the circulation tank (50), respectively, through a path that supplies liquid nitrogen directly to the heat exchanger (30) (first path) and a path that supplies it to the circulation tank (50) (second path). At this time, the amount of liquid nitrogen supplied to the circulation tank (50) via the second path is preferably maintained at an amount sufficient to completely fill the volume of the circulation tank (50) (e.g., 1 m³).

[0065] The liquid nitrogen supplied to the heat exchanger (30) via the first path is cooled through the heat exchanger (30), and the cooled liquid nitrogen is supplied to the measurement tank (60) via the first flowmeter (80) and the second flowmeter (90). In addition, the liquid nitrogen supplied to the measurement tank (60) is supplied to the circulation tank (50) through the measurement tank (60).

[0066] In addition, the liquid nitrogen supplied to the circulation tank (50) via the second path is supplied to the heat exchanger (30) as the circulation pump (40) operates. The liquid nitrogen supplied to the heat exchanger (30) is ultimately supplied to the circulation tank (50) in the same manner as the liquid nitrogen supplied to the heat exchanger (30) via the first path.

[0067] As the liquid nitrogen supplied to the heat exchanger (30) via the first and second paths is cooled through the heat exchanger (30) and the cooled liquid nitrogen circulates inside the system, the components and pipelines inside the system maintain a low-temperature state, thereby preventing the liquid nitrogen circulating inside the calibration system from vaporizing due to the rise in internal temperature during the system's measurement operation to be described later.

[0068] During the cooling operation of the system, all valves from the first valve to the twelfth valve are opened, and some of the liquid nitrogen inside the heat exchanger (30) and the measurement tank (60) is discharged to the outside

through valves v4 and v7, respectively. In addition, some of the liquid nitrogen supplied from the storage tank (10) to the circulation tank (50) is discharged to the outside through valve v12.

[0069] In addition, a plurality of temperature measuring instruments for measuring the internal temperature may be installed inside the system.

[0070] FIG. 4 is a schematic diagram showing a pressure control operation state of the cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

[0071] When liquid nitrogen is moved and stored inside the system to measure its weight, if the internal pressure of the system drops and the liquid nitrogen vaporizes into a gas-liquid two-phase flow state, an error occurs in measuring the weight of the liquid nitrogen. Therefore, the internal pressure of the system must be increased and maintained above a certain pressure to prevent the liquid nitrogen from vaporizing and generating bubbles, and for this purpose, a pressure control operation to increase and maintain the internal pressure of the system is essential.

[0072] Referring to FIG. 4, a vaporizer (20) is additionally disposed outside the cryogenic calibration system for liquid flowmeters. A pipeline formed at one end of the vaporizer (20) is connected to the storage tank (10), and a pipeline formed at the other end of the vaporizer (20) is connected to the heat exchanger (30). A third flowmeter (100) is additionally disposed in the pipeline connecting the heat exchanger (30) and the measurement tank (60). In addition, to discharge the gaseous nitrogen inside the system to the outside, a new pipeline branches off from the pipeline connecting the measurement tank (60) and the circulation tank (50). A fourth flowmeter (110) is disposed in this new pipeline.

[0073] The liquid nitrogen stored in the storage tank (10) is supplied to the vaporizer (20), and the liquid nitrogen that has passed through the vaporizer (20)

changes state to gaseous nitrogen. The gaseous nitrogen is cooled through the heat exchanger (30), and the cooled gaseous nitrogen is supplied to the components and pipelines constituting the system. The supplied gaseous nitrogen pressurizes the inside of the system to increase the internal pressure, and thereafter maintains the internal pressure at a constant pressure.

[0074] At this time, valves v7 and v14 are closed and valve v13 is opened to pressurize the inside of the system. If the system is to be depressurized after pressurization, valves v7, v13, and v14 are all opened to discharge the gaseous nitrogen inside the system to the outside.

[0075] The supply amount of gaseous nitrogen supplied from the heat exchanger (30) to the measurement tank (60) is measured by the third flowmeter (100), and the discharge amount of gaseous nitrogen discharged from inside the system to the outside is measured by the fourth flowmeter (110). In addition, the amount of gaseous nitrogen remaining inside the system is calculated based on the difference between the measured supply amount and discharge amount of gaseous nitrogen. A plurality of pressure measuring instruments is installed inside the system to measure the internal pressure.

[0076] FIG. 5 is a schematic diagram showing a circulation operation state of the cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

[0077] Referring to FIG. 5, when the temperature and pressure inside the cryogenic calibration system for liquid flowmeters (1) are confirmed to be maintained at preset temperatures and pressures—as measured by the plurality of temperature and pressure measuring instruments installed inside the system—such that the liquid nitrogen does not vaporize, valves v5, v6, v8, v9, and v10 of the system are opened, and all remaining valves are closed.

[0078] Thereafter, the liquid nitrogen continuously circulates through a

circulation loop in which the heat exchanger (30), measurement tank (60), circulation tank (50), and circulation pump (40) are connected to each other by pipelines.

[0079] At this time, the circulation pump (40) continues to operate without stopping, so that the liquid nitrogen stored in the circulation tank (50) continues to circulate inside the system. The circulation pump (40) adjusts the flow rate of the liquid nitrogen using an inverter in the range of 20 to 60 Hz, and supplies liquid nitrogen at a rate of 20 m³ per hour.

[0080] FIG. 6 is a schematic diagram showing a calibration operation state of the cryogenic calibration system for liquid flowmeters according to an embodiment of the present invention.

[0081] Referring to FIG. 6, when the liquid nitrogen circulating inside the cryogenic calibration system for liquid flowmeters (1) reaches a flow-stabilized state in which it circulates stably while maintaining a constant temperature and pressure, valve v8 is closed and the flow path of the liquid nitrogen is changed. A solenoid valve may be used as valve v8, and the time to switch the flow path using valve v8 must be less than 100 ms.

[0082] When the flow path is switched, liquid nitrogen is stored in the measurement tank (60) for a predetermined period of time. While the liquid nitrogen is being stored in the measurement tank (60), the scale (70) provided at the lower end of the measurement tank (60) measures the weight of the stored liquid nitrogen in real time. Thereafter, the flow rate of the second flowmeter (90) is calibrated based on the weight values measured by the scale (70). At this time, the measurement tank (60) is equipped with a level sensor that measures the height of the stored liquid nitrogen.

[0083] Although the present invention was described with reference to limited drawings, the above description is provided as an exemplary example of the

present invention, and it should be understood that the present invention may be easily modified in other various ways without changing the spirit or the necessary features of the present invention by those skilled in the art. Therefore, the examples described above are only exemplary and should not be construed as being limitative in all respects. For example, the components described as single parts may be divided and the components described as separate parts may be integrated. Further, the techniques described above may be performed in a different order from the described method.

[0084] The embodiments described herein and the accompanying drawings merely illustrate some of the technical ideas included in the present invention. Therefore, the scope of the present invention is defined by the appended claims, and all modifications or variations derived from the meaning and scope of the claims and their equivalents should be interpreted as falling within the scope of the present invention.

[0086] <Description of Reference Numerals>

[0087] 1: Cryogenic Calibration System for Liquid Flowmeters

[0088] 10: Storage Tank

[0089] 20: Vaporizer

[0090] 30: Heat Exchanger

[0091] 40: Circulation Pump

[0092] 50: Circulation Tank

[0093] 60: Measurement Tank

[0094] 70: Scale

[0095] 80: First Flowmeter

[0096] 90: Second Flowmeter (Flowmeter under Calibration)

[0097] 100: Third Flowmeter

[0098] 110: Fourth Flowmeter

【CLAIMS】**【Claim 1】**

A cryogenic calibration system for liquid flowmeters, comprising:
a heat exchanger configured to cool a liquefied gas supplied from a circulation tank using liquefied gas stored in a storage tank, and to supply the liquefied gas to a measurement tank;
a vaporizer configured to vaporize the liquefied gas stored in the storage tank and to supply it to the heat exchanger;
the measurement tank configured to measure the weight of the liquefied gas supplied from the heat exchanger through a scale provided at its lower end;
the circulation tank configured to store the liquefied gas whose measurement is completed in the measurement tank;
a circulation pump configured to supply the liquefied gas stored in the circulation tank to the heat exchanger; and
a flow path switching valve configured to block the supply of liquefied gas from the measurement tank to the circulation tank, and to change the flow path of the liquefied gas so that the liquefied gas is stored in the measurement tank,
wherein a weight value of the liquefied gas stored in the measurement tank for a period of time is measured by the scale, and the flow rate value of the liquid flowmeter is calibrated based on the measured weight value.

【Claim 2】

The cryogenic calibration system for liquid flowmeters of claim 1,
wherein the flow path switching valve is a solenoid valve.

【Claim 3】

The cryogenic calibration system for liquid flowmeters of claim 1, wherein the measurement tank is manufactured as a double-walled vessel, and a vacuum is formed between inner and outer vessels constituting the double-walled vessel.

【Claim 4】

The cryogenic calibration system for liquid flowmeters of claim 1, wherein the storage tank, vaporizer, heat exchanger, measurement tank, circulation tank, and circulation pump are connected to each other by pipelines, wherein the pipelines are configured as inner and outer double pipelines, and a vacuum is formed between the double pipelines.

【Claim 5】

A method of operating a cryogenic calibration system for liquid flowmeters, the method comprising:

a cooling operation step of cooling a liquefied gas supplied from a storage tank through a heat exchanger, and supplying the cooled liquefied gas to a measurement tank, a circulation tank, and a circulation pump, which are sequentially connected to each other through a pipe, to cool the devices and the pipe;

a pressure control operation step of vaporizing the liquefied gas supplied from the storage tank through a vaporizer, and sequentially supplying the vaporized gas to the measurement tank and the circulation tank to pressurize the devices and the pipe;

a circulation operation step of circulating the liquefied gas through a circulation

loop in which the measurement tank, the circulation tank, the circulation pump, and the heat exchanger are sequentially connected to each other through the pipe, after the cooling operation step and the pressure control operation step, when the liquefied gas reaches a flow stabilization state under a constant temperature and pressure; and

a changing step of a flow path of the liquefied gas by controlling a flow path switching valve such that the liquefied gas supplied to the circulation tank is stored in the measurement tank.

【Claim 6】

The method of operating a cryogenic calibration system for liquid flowmeters of claim 5, further comprising:

a measuring step of a weight value of the stored liquefied gas in real time through a scale provided at a lower portion of the measurement tank, when the liquefied gas is stored in the measurement tank for a certain period of time.

【Claim 7】

The method of operating a cryogenic calibration system for liquid flowmeters of claim 6, further comprising:

a calibration operation step of calibrating a flow rate value of the liquid flowmeter based on the measured weight value.

【Claim 8】

The method of operating a cryogenic calibration system for liquid flowmeters of claim 5,

wherein in the cooling operation step, the liquefied gas is supplied from the

storage tank to the circulation tank, the liquefied gas supplied to the circulation tank is supplied to the heat exchanger through the circulation pump, and the cooled liquefied gas is supplied to the measurement tank, the circulation tank, and the circulation pump sequentially connected to each other via a pipe, thereby cooling the devices and pipes.

【Claim 9】

The method of operating a cryogenic calibration system for liquid flowmeters of claim 5,
wherein the flow path switching valve is a solenoid valve.

【Claim 10】

The method of operating a cryogenic calibration system for liquid flowmeters of claim 5,
wherein the measurement tank is manufactured as a double-walled vessel, and a vacuum is formed between outer and inner vessel constituting the double-walled vessel.

【Claim 11】

The method of operating a cryogenic calibration system for liquid flowmeters of claim 5,
wherein the pipelines connecting the storage tank, the vaporizer, the heat exchanger, the measurement tank, the circulation tank, and the circulation pump are configured as a double pipeline comprising inner and outer pipes, and a vacuum is formed between the inner and outer pipes.