US Patent & Trademark Office
Patent Public Search | Text View

United States Patent	12385772
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Lee; Seung Chan et al.

Water level measurement system

Abstract

A water level measurement system according to an embodiment of the present invention includes a support pipe installed in a water tank filled with a fluid to measure a water level and extending in a depth direction of the water tank, a support rod disposed in an inner space of the support pipe and extending in the depth direction of the water tank, a plurality of ultrasonic probes attached to the support rod and generating ultrasonic waves, and a water level calculator connected to the plurality of ultrasonic probes and calculating the water level in the water tank, wherein the water level calculator calculates the water level of the water tank by using an order of the ultrasonic probes disposed at a highest position among the plurality of ultrasonic probes that detect a signal of a reflected wave reflected from the support pipe.

Inventors:	**Lee; Seung Chan (Daejeon, KR), Yoon; Duk-Joo (Daejeon, KR), Kim; Yo-Han (Daejeon, KR)**
Applicant:	**KOREA HYDRO & NUCLEAR POWER CO., LTD.** (Gyeongju-si, KR)
Family ID:	**1000008750610**
Assignee:	**KOREA HYDRO & NUCLEAR POWER CO., LTD. (Gyeongju-si, KR)**
Appl. No.:	**18/029191**
Filed (or PCT Filed):	**September 27, 2021**
PCT No.:	**PCT/KR2021/013162**
PCT Pub. No.:	**WO2022/071705**
PCT Pub. Date:	April 07, 2022

Prior Publication Data

Document Identifier	**Publication Date**

Foreign Application Priority Data

KR	10-2020-0127574	Sep. 29, 2020

Publication Classification

Int. Cl.: **G01D11/30** (20060101); **G01F23/296** (20220101); **G21C19/07** (20060101)

U.S. Cl.:

CPC **G01F23/2961** (20130101); **G01D11/30** (20130101); **G21C19/07** (20130101);

Field of Classification Search

CPC: G01F (23/2961); G01D (11/30); G21C (19/07)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
5697248	12/1996	Brown	73/290V	G01F 23/28
2010/0132453	12/2009	Dam	73/290V	G01F 23/2962
2014/0260521	12/2013	McQueen et al.	N/A	N/A
2014/0334983	12/2013	Yang	422/119	B01D 53/9495
2016/0061645	12/2015	Birtcher	73/290V	G01F 23/2965

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
100455999	12/2008	CN	N/A
105136222	12/2014	CN	N/A
107024256	12/2016	CN	G01F 23/2962
2990770	12/2015	EP	G01F 23/296
125173	12/2014	FI	N/A
2036325	12/1979	GB	G01F 23/2961
2312509	12/1996	GB	N/A
2312509	12/1996	GB	G01F 23/2961
56130616	12/1980	JP	N/A
S56130616	12/1980	JP	N/A
H05273033	12/1992	JP	N/A
H11218436	12/1998	JP	N/A
2010-276593	12/2009	JP	N/A
5159645	12/2012	JP	N/A
2013-140029	12/2012	JP	N/A
2014-224818	12/2013	JP	N/A
10-2011-0116747	12/2010	KR	N/A

2011116747	12/2010	KR	N/A
10-2014-0094715	12/2013	KR	N/A
10-2016-0026733	12/2015	KR	N/A
10-1636951	12/2015	KR	N/A
2003/012379	12/2002	WO	N/A

OTHER PUBLICATIONS

EPO, Search Report of EP 21875980.1 dated Oct. 8, 2024, total 8 pages. cited by applicant

Primary Examiner: Williams; Jamel E

Attorney, Agent or Firm: LEX IP MEISTER, PLLC

Background/Summary

TECHNICAL FIELD

(1) The present invention relates to a water level measurement system, and more particularly, to a water level measurement system using ultrasonic waves.

BACKGROUND ART

(2) In general, the level of cooling water filled inside a nuclear fuel reloading tank or a nuclear fuel storage tank of a nuclear power plant is monitored, and a safety response system and procedure should be prepared accordingly. That is, in the nuclear fuel reloading tank or the nuclear fuel storage tank, the cooling process is performed for the decay heat, and the forced cooling by a pump is performed. At this time, in the case of the nuclear fuel storage tank, when the cooling function is lost or the forced circulation is not performed, the fuel storage storage tank boils and then the steam may be mixed. At this time, the water level must be monitored so that an alternative water source can be mobilized immediately, and the condition thereof must be monitored through continuous water level monitoring even after the alternative water source is fed into the water.

(3) In general, a water level measurement method of a differential pressure type or a water level measurement method of an ultrasonic wave type is used to measure the water level. In the water level measurement method of the differential pressure type, when bubbles or steam are generated inside the water tank, it is difficult to measure the water level by differential pressure due to rapid fluctuations of the fluid. The water level measurement method of the ultrasonic wave measures the water level by calculating the time between ultrasonic waves emitted and ultrasonic waves reflected in a dense medium such as a liquid or by using an interference fringe of the ultrasonic waves. The water level measurement method of the ultrasonic wave is highly correlated with the presence of reflected waves reflected after the ultrasonic waves are transmitted through the dense medium. When conditions are not normal, that is, when the cooling function of the nuclear fuel reloading tank or the nuclear fuel storage tank is lost, the boiling occurs in the cooling water, and bubbles or steam are rapidly generated, it is difficult to calculate a standardized reflected wave because the reflected wave is extinguished or lost. Therefore, it is difficult to accurately measure the reflected wave, and there is a limit to measuring the water level. In particular, when the bubbles are generated, it is difficult to accurately measure the water level because the waveform of the ultrasonic wave is uneven.

(4) In order to supplement these water level measurement methods, a thermal contact radar method, a thermal diffusion radar method, or a method of measuring the water level by imitating the shape of a radar are used, but in these methods, complex modules or equipment for analysis and interpretation are combined an equipment for analyzing radar-type data must be installed, so the

price and cost of the equipment itself increases.

DISCLOSURE

Technical Problem

(5) The present embodiment relates to a water level measurement system capable of accurately measuring a water level even under abnormal conditions.

Technical Solution

(6) A water level measurement system according to an embodiment includes a support pipe installed in a water tank filled with a fluid to measure a water level and extending in a depth direction of the water tank, a support rod disposed in an inner space of the support pipe and extending in the depth direction of the water tank, a plurality of ultrasonic probes attached to the support rod and generating ultrasonic waves, and a water level calculator connected to the plurality of ultrasonic probes and calculating the water level in the water tank, wherein the water level calculator calculates the water level of the water tank by using an order of the ultrasonic probes disposed at a highest position among the plurality of ultrasonic probes that detect a signal of a reflected wave reflected from the support pipe.

(7) When the number of the plurality of ultrasonic probes is N, a length of the support rod is L, and the order of the ultrasonic probes disposed at the highest position among the ultrasonic probes that detect the signal of the reflected wave is S, the water level of the water tank may be calculated as $(L/N)*S$.

(8) The support rod may be disposed on a central axis of the support pipe.

(9) The support rod may be disposed on one side of the support pipe based on the central axis of the support pipe.

(10) The plurality of ultrasonic probes may propagate the ultrasonic wave in a horizontal direction parallel to a surface of the fluid.

(11) The plurality of ultrasonic probes may be disposed in the depth direction of the water tank.

(12) The water tank may include a nuclear fuel reloading tank or a nuclear fuel storage tank of a nuclear power plant.

Advantageous Effects

(13) According to an embodiment, since ultrasonic waves propagate a space between the support rod and the inner wall of the support pipe, where bubbles or steam are not generated, the water level can be accurately measured even under abnormal conditions in which bubbles or steam are generated inside the water tank.

(14) In addition, since the water level of the fluid filled in the water tank can be measured using an ultrasonic probe, which is a low-cost apparatus, the water level can be quickly measured at a low cost compared to a method using expensive radar-type equipment.

Description

DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a drawing schematically illustrating a state in which a water level measurement system according to an embodiment is installed in a water tank.

(2) FIG. **2** is a partially enlarged view of a water level measurement system according to an embodiment, and is a drawing illustrating a state in which ultrasonic waves propagate above and below the water surface.

(3) FIG. **3** is a drawing schematically illustrating a state in which a water level measurement system according to another embodiment is installed in a water tank.

(4) FIG. **4** is a partially enlarged view of a water level measurement system according to another embodiment, and is a drawing illustrating a state in which ultrasonic waves propagate above and below the water surface.

MODE FOR INVENTION

(5) Hereinafter, in order to aid understanding of the present invention, various embodiments of the present invention will be described in detail so that those skilled in the art can easily carry out the present invention with reference to the accompanying drawings. The present disclosure may be embodied in many different forms and is not limited to the embodiments described herein.

(6) In order to clearly illustrate the present disclosure, parts that are not related to the description are omitted, and the same or similar constituent elements are given the same reference numerals throughout the specification.

(7) In addition, since the size and thickness of each configuration shown in the drawing are arbitrarily shown for better understanding and ease of description, the present disclosure is not necessarily limited to the illustrated one.

(8) FIG. **1** is a drawing schematically illustrating a state in which a water level measurement system according to an embodiment is installed in a water tank, FIG. **2** is a partially enlarged view of a water level measurement system according to an embodiment, and is a drawing illustrating a state in which ultrasonic waves propagate above and below the water surface.

(9) As shown in FIGS. **1** and **2**, a water level measurement system according to an embodiment includes a support pipe **100**, a support rod **200**, a plurality of ultrasonic probes **300**, a water level calculator **400**, and a plurality of fixing member **500**.

(10) The support pipe **100** may be installed in the water tank **10** filled with the fluid **1** to measure the water level. The support pipe **100** may extend long in the depth direction Y of the water tank **10** and may have a predetermined length L. The support pipe **100** may have a lower portion disposed below a water surface **1***a* of the fluid **1** filled in the water tank **10** and an upper portion disposed above the water surface **1***a* of the fluid **1**. Thus, the fluid **1** may be filled in the inner space O of the support pipe **100**. The support pipe **100** may be made of a material such as metal. The water tank **10** may include a nuclear fuel reloading tank or a nuclear fuel storage tank of a nuclear power plant. Therefore, the present invention can monitor the water level of the cooling water filled inside the water tank **10** of the nuclear power plant. However, the present invention is not necessarily limited thereto and can be applied to various water tanks.

(11) The support rod **200** may be disposed in the inner space O of the support pipe **100**. The support rod **200** may be disposed on the central axis C of the support pipe **100** and may extend in the depth direction Y. The length L of the support rod **200** may be the same as the length L of the support pipe **100**. However, it is not necessarily limited thereto, and the length L of the support rod **200** may be different from the length L of the support pipe **100** according to the embodiment. The support rod **200** may be spaced apart from the inner wall of the support pipe **100** by a predetermined distance D and disposed on the central axis C of the support pipe **100**. Therefore, the fluid **1** may be disposed in a narrow space between the inner wall of the support pipe **100** and the support rod **200**. Therefore, even under abnormal conditions in which boiling occurs in the water tank **10** and bubbles or steam are generated, bubbles or steam hard to exist in the fluid **1** disposed in the narrow space between the inner wall of the support pipe **100** and the support rod **200**.

(12) A plurality of ultrasonic probes **300** may be attached to the circumferential surface of the support rod **200** to generate ultrasonic waves and detect reflected waves R. Also, the plurality of ultrasonic probes **300** may propagate the ultrasonic waves in a horizontal direction X parallel to the surface **1***a* of the fluid **1**. Therefore, ultrasonic waves generated by the plurality of ultrasonic probes **300** may propagate to the inner wall of the support pipe **100**. At this time, since it is difficult for bubbles or steam to exist on the path of ultrasonic waves, the water level may be accurately measured.

(13) The plurality of ultrasonic probes **300** may be spaced apart at predetermined gap in the depth direction Y of the water tank **10**.

(14) The ultrasonic probe **300** may include a plurality of sub ultrasonic probes **310** and **320** installed at the same height and spaced apart from each other. Therefore, since ultrasonic waves can

be generated in various directions of the support rod **200**, the water level can be more accurately measured. Although two sub-ultrasonic probes are shown in this embodiment, it is not necessarily limited thereto, and the number of sub-ultrasonic probes may be variously changed.

(15) At this time, the support rod **200** filling the inside does not directly contact the inner wall of the support pipe **100**, and the support rod **200** and the support pipe **100** may be spaced apart from each other. Therefore, the vibration of ultrasonic waves generated from the plurality of ultrasonic probes **300** attached to the support rod **200** may not directly affect the support pipe **100** spaced apart from the support rod **200**, so that the interference of ultrasonic waves is removed, thereby more accurately measuring the water level.

(16) That is, since the ultrasonic probe **300** is attached to the fixed support rod **200** filling the inside to transmit ultrasonic waves to the support pipe **100** that does not directly contact the ultrasonic probe **300**, ultrasonic waves between the ultrasonic probe **300** do not interfere with each other, thereby generating interference signals or noise signals. Therefore, since complicated additional equipment such as an arithmetic processing device for processing the interference signals or noise signals is not required, and each ultrasonic probe **300** independently measures the water level, a simple structure is possible and manufacturing costs can be minimized.

(17) Since the ultrasonic wave L**1** generated by the ultrasonic probe **300** disposed below the water surface **1***a* propagates inside the fluid **1**, a reflected wave is generated on the inner wall of the support pipe **100**, and since the reflected wave R is returned to the ultrasonic probe **300**, the ultrasonic probe **300** can detect the reflected wave.

(18) In addition, since the ultrasonic wave L**2** generated by the ultrasonic probe **300** disposed above the water surface **1***a* does not propagates inside the fluid **1**, it is dissipated or scattered on the inner wall of the support pipe **100**, so that the ultrasonic probe **300** cannot detect the reflected wave R.

(19) The water level calculator **400** may be connected to the plurality of ultrasonic probes **300** to calculate the water level of the water tank **10**. The water level calculator **400** can calculate the water level of the water tank **10** by using the order of the ultrasonic probes disposed at the highest position among the ultrasonic probes **300** that detect the signal of the reflected wave R reflected from the support pipe **100**.

(20) At this time, the ultrasonic probe **300** disposed at the highest position among the ultrasonic probes **300** that detect the signal of the reflected wave R may compare and confirm the position of the ultrasonic probe **300** that detects the signal of the reflected wave through an AND logic gate.

(21) Each ultrasonic probe **300** may serve as a channel for measuring the water level. The AND logic gate of the water level calculator **400** may compare channels between ultrasonic probes **300** adjacent to each other. At this time, as the water level rises step by step, the signal of the final reflected wave among the signals of the reflected wave R detected by the ultrasonic probe **300** can be confirmed by comparing each channel with each other. Therefore, the level of the water tank **10** can be calculated by comparing the ultrasonic probe **300**, that is, the channel where the signal of the final reflected wave is detected, and confirming the signal of the reflected wave at the highest position. In FIG. **1**, since the signal of the eighth reflected wave R**8** is detected by using the AND logic gate of the water level calculator **400**, the order of the ultrasonic probe **300**, which is disposed at the highest position among the plurality of ultrasonic probes **300** that detect the signal of the reflected wave R, may be calculated as eight.

(22) When the number of the plurality of ultrasonic probes **300** is N, the length of the support rod **200** (or the support pipe **100**) is L, and the order of the ultrasonic probe **300** disposed at the highest position among the plurality of ultrasonic probes **300** that detects the signal of the reflected wave R is S, the water level P of the water tank **10** can be expressed by Equation 1 below. Here, the order of the ultrasonic probe **300** means the order calculated from the lower end of the support rod **200**.

$P=(L/N)*S$ [Equation 1]

(23) At this time, each ultrasonic probe **300** may serve as a channel for measuring the water level. That is, when the water level is to be measured with 100 channels in the water tank **10** filled with

the fluid **1** having a water level of 6 m, 100 ultrasonic probes **300** may be installed on the support rod **200** with the length of 6 m, and one ultrasonic probe **300** may be disposed every 6 cm.
(24) In addition, when the water level is to be measured with 150 channels in the water tank **10** having a water level of 4 m, 150 ultrasonic probes **300** may be installed on the support rod **200** with the length of 4 m, and one ultrasonic probe **300** may be disposed every 2.67 cm.
(25) When the channel disposed at the highest position among channels in which the signal of the reflected wave is detected is 123, that is, the order of the ultrasonic probe **300** disposed at the highest position among the plurality of ultrasonic probes **300** that detect the signal of the reflected wave is 123, the water level P of the water tank **10** can be calculated as (400 cm/150)*123=328.41 Cm.
(26) In addition, by increasing the number of channels, that is, the number of the ultrasonic probes **300**, the water level of the water tank **10** can be more accurately measured.
(27) As described above, in the water level measurement system according to an embodiment of the present invention, the ultrasonic waves propagate between the support rod **200** and the inner wall of the support pipe **100**, which is a space where no bubbles or steam are generated, so that the water level of the fluid **1** filled inside the water tank **10** can be more accurately measured.
(28) In addition, since the water level of the fluid **1** filled in the water tank **10** can be measured using the ultrasonic probe **300**, which is a low-cost apparatus, the water level can be quickly measured at a low cost compared to a method using expensive radar-type equipment.
(29) The plurality of fixing members **500** may fix the support rod **200** inside the support pipe **100** by connecting the inner wall of the support rod **200** and the support pipe **100** to each other. The fixing member **500** may be disposed between the ultrasonic probes **300** neighboring up and down. Therefore, shaking of the support rod **200** can be prevented, and the water level can be more accurately measured by the ultrasonic probe **300**.
(30) On the other hand, in the above embodiment, the support rod is disposed on the central axis of the support pipe, but another embodiments in which the support rod is disposed on one side of the support pipe based on the central axis of the support pipe are also possible.
(31) Hereinafter, a water level measurement system according to another embodiment of the present invention will be described in detail with reference to FIGS. **3** and **4**.
(32) FIG. **3** is a drawing schematically illustrating a state in which a water level measurement system according to another embodiment is installed in a water tank, FIG. **4** is a partially enlarged view of a water level measurement system according to another embodiment, and is a drawing illustrating a state in which ultrasonic waves propagate above and below the water surface.
(33) The another embodiments shown in FIGS. **3** and **4** are substantially the same as those of the embodiment shown in FIGS. **1** and **2** except for the position of the support rod, and repeated descriptions are omitted.
(34) As shown in FIGS. **3** and **4**, a water level measurement system according to another embodiment includes a support pipe **100**, a support rod **200**, a plurality of ultrasonic probes **300**, a water level calculator **400**, and a plurality of fixing member **500**. The support rod **200** may be disposed on one side of the support pipe **100** based on the central axis C of the support pipe **100** and may extend in the depth direction Y. The support rod **200** may be disposed on one side of the support pipe **100** in contact with the inner wall of the support pipe **100**.
(35) At this time, the side wall to which the plurality of ultrasonic probes **300** are attached among the side walls of the filled support rod **200** may not directly contact the inner wall of the support pipe **100** facing the same each other and may have a structure separated from each other. Therefore, the vibration of ultrasonic waves generated from the plurality of ultrasonic probes **300** attached to the support rod **200** may not directly affect the support pipe **100** spaced apart from the support rod **200**, so that the interference of ultrasonic waves is removed, thereby more accurately measuring the water level.
(36) That is, since the ultrasonic probe **300** is attached to the fixed support rod **200** filling the inside

to transmit ultrasonic waves to the support pipe **100** that does not directly contact the ultrasonic probe **300**, ultrasonic waves between the ultrasonic probe **300** do not interfere with each other, thereby generating interference signals or noise signals. Therefore, since complicated additional equipment such as an arithmetic processing device for processing the interference signals or noise signals is not required, and each ultrasonic probe **300** independently measures the water level, a simple structure is possible and manufacturing costs can be minimized.
(37) The water level calculator **400** may be connected to the plurality of ultrasonic probes **300** to calculate the water level of the water tank **10**. The water level calculator **400** can calculate the water level of the water tank **10** by using the order of the ultrasonic probe **300** disposed at the highest position among the ultrasonic probes **300** that detect the signal of the reflected wave R reflected from the support pipe **100**.
(38) At this time, the ultrasonic probe **300** disposed at the highest position among the ultrasonic probes **300** that detect the signal of the reflected wave R may compare and confirm the position of the ultrasonic probe **300** that detects the signal of the reflected wave through an AND logic gate.
(39) Each ultrasonic probe **300** may serve as a channel for measuring the water level. The AND logic gate of the water level calculator **400** may compare channels between ultrasonic probes **300** adjacent to each other. At this time, as the water level rises step by step, the signal of the final reflected wave among the signals of the reflected wave R detected by the ultrasonic probe **300** can be confirmed by comparing each channel with each other. Therefore, the level of the water tank **10** can be calculated by comparing the ultrasonic probe **300**, that is, the channel where the signal of the final reflected wave is detected, and confirming the signal of the reflected wave at the highest position. In FIG. **3**, since the signal of the twelfth reflected wave R**12** is detected by using the AND logic gate of the water level calculator **400**, the order of the ultrasonic probe **300**, which is disposed at the highest position among the plurality of ultrasonic probes **300** that detect the signal of the reflected wave R, may be calculated as twelve.
(40) when the water level is to be measured with 150 channels in the water tank **10** having a water level of 4 m, 150 ultrasonic probes **300** may be installed on the support rod **200** with the length of 4 m, and one ultrasonic probe **300** may be disposed every 2.67 cm.
(41) When the channel disposed at the highest position among channels in which the signal of the reflected wave is detected is 12, that is, the order of the ultrasonic probe **300** disposed at the highest position among the plurality of ultrasonic probes **300** that detect the signal of the reflected wave is 12, the water level P of the water tank **10** can be calculated as (400 cm/150)*12=32 cm.
(42) The plurality of fixing members **500** may fix the plurality of ultrasonic probes **300** to the support rod **200**. The fixing member **500** may include a first fixing member **510** and a second fixing member **520** respectively installed in contact with the upper and lower surfaces of the ultrasonic probe **300**. Since shaking of the ultrasonic probe **300** can be prevented by using the first fixing member **510** and the second fixing member **520**, the water level can be more accurately measured by the ultrasonic probe **300**.
(43) Although the present disclosure has been described through preferred embodiments as described above, the present invention is not limited thereto and various modifications and variations are possible without departing from the scope of the claims described below. Those in the field will easily understand.

Claims

1. A water level measurement system comprising: a support pipe installed in a water tank filled with a fluid to measure a water level and extending in a depth direction of the water tank, a support rod disposed in an inner space of the support pipe and extending in a depth direction of the water tank, a plurality of ultrasonic probes attached to the support rod and generating ultrasonic waves, and a water level calculator connected to the plurality of ultrasonic probes and calculating the water

level of the water tank, wherein the plurality of ultrasonic probes are configured to propagate the ultrasonic waves in a horizontal direction parallel to a surface of the fluid and detect reflected waves of the ultrasonic waves reflected by an interior surface of the support pipe and propagating in the horizontal direction, and the water level calculator calculates the water level of the water tank by using an order of the ultrasonic probes disposed at a highest position among the plurality of ultrasonic probes that detect a signal of a reflected wave reflected from the support pipe.
2. The water level measurement system of 1, wherein when the number of the plurality of ultrasonic probes is N, a length of the support rod is L, and the order of the ultrasonic probes disposed at the highest position among the ultrasonic probes that detect the signal of the reflected wave is S, the water level of the water tank is calculated as $(-L/N)*S$.
3. The water level measurement system of 1, wherein the support rod is disposed on the central axis of the support pipe.
4. The water level measurement system of 1, wherein the support rod is disposed on one side of the support pipe based on the central axis of the support pipe.
5. The water level measurement system of 1, wherein the plurality of ultrasonic probes are disposed in the depth direction of the water tank.
6. The water level measurement system of 1, wherein the water tank includes a nuclear fuel reloading tank or a nuclear fuel storage tank of a nuclear power plant.
7. The water level measurement system of claim 3, wherein the support rod and the support pipe do not directly contact each other.
8. The water level measurement system of claim 4, wherein the ultrasonic probe is installed at a position facing an exposed inner wall of the support pipe.