# METHOD FOR DETECTING WATER LEVEL OF HEAT TRANSFER TUBES AND METHOD FOR INSPECTING HEAT TRANSFER TUBES

Field of the Invention

[0001] The present invention relates to a method for detecting a water level of heat transfer tubes and a method for inspecting heat transfer tubes.

Description of Related Art

Background Art of the Invention

[0002] There is a system in which, to perform wall thickness measurement or flaw inspection of a heat transfer tube (a boiler tube), an ultrasonic sensor is introduced from a header to which a plurality of heat transfer tubes are connected, and inspection is performed. In the event of the inspection, since the heat transfer tube that is an inspection object should be filled with water, the supply of water is performed using a water supply facility of a boiler (e.g., see Patent Document 1).

[0003] When the plurality of heat transfer tubes connected to the header are inspected, an end of the header of the object is cut to introduce the ultrasonic sensor into the header. However, when water is accumulated up to an upper side above the header, water to which a pressure is applied is spouted when the header is cut. Thus, the water in the header is drained, whereas the inside of the heat transfer tube needs to be filled with water without deficiency or excess. Especially, since the headers are scattered in a vertical direction of the boiler, it is necessary to be careful when the header positioned below is cut.

[0004] Conventionally, to perform water filling without deficiency or excess, following processes are performed.

(1) Completely draining the water inside the heat transfer tube temporarily,

(2) Cutting and opening the inspection nozzle formed on the header,

(3) Supplying water, and

(4) Stopping the supply of water if the water overflows from the cut

inspection nozzle

Prior Art Documents

[0005] Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2001-305110

Patent Document 2: Japanese Unexamined Patent Application, First Publication No. S60-36803

## SUMMARY OF THE INVENTION

[0006] Meanwhile, when the water filling is performed in the aforementioned procedure, there is a problem that effort and cost are required because of the plurality of headers. When the aforementioned procedure is performed on each of the plurality of headers, there is also a problem that a large amount of water is required and much drainage is caused.

[0007] In Patent Document 2, a technique in which, to check that water remains in the heat transfer tube, a probe of the ultrasonic sensor is applied from the outside of the heat transfer tube, and waveforms thereof are observed, and thereby it is checked whether or not there is remaining water is described. However, the technique described in Patent Document 2 is merely a way of detecting the remaining water in the heat transfer tube after completely blowing (draining). Even when this way is used, the heat transfer tube connected to the header of the object is covered with a refractory, and the ultrasonic sensor cannot be applied if the refractory is not removed. Even if the refractory is removed, there is a problem that operation is difficult because the operation is performed at a high location with no scaffold.

[0008] This invention is directed to providing a method for detecting a water level of heat transfer tubes, capable of easily obtaining a state in which water in a header is drained and the heat transfer tube is filled with water, and a method for inspecting the heat transfer tubes.

[0009] According to a first aspect of the present invention, a method for detecting a water level of heat transfer tubes is a method for detecting a water level of a plurality of heat transfer tubes extending downward from a header lying in a horizontal direction, and includes: a transmission process of continuously transmitting ultrasonic waves upward from an ultrasonic sensor to a lower surface of an inspection nozzle horizontally protruding from the header; a drainage process of performing drainage from the heat transfer tube and the header; a drainage stoppage process of stopping the drainage at a point in time when a state in which a reflected signal of the ultrasonic waves is detected by the ultrasonic sensor changes to a state in which the reflected signal is not detected due to the drainage; and an opening process of opening at least a part of the inspection nozzle after the stoppage of the drainage.

[0010] According to this constitution, drainage can be stopped in a state in which water in the header is drained along with the inside of the heat transfer tube is filled with water. Thereby, the state in which the water in the header is drained and the inside of the heat transfer tube is filled with water can be easily acknowledged.

In addition, since a change in the water level can be detected without removing a refractory for protecting the heat transfer tube, the water level can be detected at a low cost and in a short operation time.

[0011] In the method for detecting a water level of heat transfer tubes, the inspection nozzle may be located close to a passage at a predetermined interval from a top surface of the passage.

[0012] According to this constitution, since operation for the detection on the passage is possible, the operation can be safely performed.

[0013] According to a second aspect of the present invention, a method for inspecting heat transfer tubes is performed after the method for detecting a water level of heat transfer tubes according to any of the constitutions, the method includes an ultrasonic sensor insertion process of inserting the ultrasonic sensor for a heat transfer tube from the inspection nozzle into the heat transfer tube.

[0014] According to this constitution, inspection can be safely performed from the state in which the heat transfer tube is filled with water.

[0015] According to the present invention, drainage can be stopped in a state in which water in a header is drained and the inside of a heat transfer tube is filled with water. Thereby, the state in which the inside of the heat transfer tube is filled with water can be easily obtained.

Since a change in the water level can be detected without removing a refractory for protecting the heat transfer tube, the water level can be detected at a low cost and in a short operation time.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 includes a perspective view of a boiler and a tube wall thickness measurement system of an embodiment of the present invention.

FIG. 2 includes a schematic view of the boiler of the embodiment of the present invention.

FIG. 3 includes views of a header and an inspection nozzle of the embodiment of the present invention showing a state in which the header is filled with water.

FIG. 4 includes views of the header and the inspection nozzle of the embodiment of the present invention showing a state in which the water in the header is reduced.

FIG. 5 includes views of the header and the inspection nozzle of the embodiment of the present invention showing a state in which water in the inspection nozzle is emptied.

FIG. 6 is a graph showing a time-dependent change in magnitude of a reflected signal of ultrasonic waves.

FIG. 7 is a flow chart of a method for detecting a water level of heat transfer tubes of the embodiment of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

[0017] Hereinafter, an embodiment of a method for detecting a water level of heat transfer tubes of the present invention and an embodiment of a method for inspecting heat transfer tubes will be described in detail with reference to the drawings.

The method for detecting a water level of heat transfer tubes of the present invention is a method for checking that, for instance, when wall thickness measurement or flaw inspection of a heat transfer tube used in a boiler constituting a stoker type incinerator is performed, the inside of the heat transfer tube is filled with water, and water inside a header connected to top ends of the heat transfer tubes is drained.

[0018] Here, a tube wall thickness measurement system for performing the wall thickness measurement or the flaw inspection of the heat transfer tube using a sensor such as an ultrasonic probe (hereinafter referred to as an ultrasonic sensor for a heat transfer tube) will be described.

[0019] As shown in FIG. 1, a boiler 10 includes a header 12 lying in a horizontal direction, and a plurality of heat transfer tubes 11 extending downward from the header 12. The heat transfer tubes 11 are a plurality of rigid tubes that are channels for steam, and are arranged in an extending direction of the header 12 such that they are in parallel with each other, and one end of each thereof is connected to the header 12. Each of the heat transfer tubes 11 communicates with the header 12, and extends to be orthogonal to the header 12.

[0020] An inspection nozzle 13 used in the event of inspection is formed on the header 12 so as to horizontally protrude from an end of the header 12 in the horizontal direction.

According to an arrangement or a size of the header 12, a plurality of the inspection nozzles 13 may formed on a middle section of the header 12.

The ultrasonic sensor 6 for a heat transfer tube is introduced into the heat transfer tube 11 via the header 12 and an inspection hole 13a formed by opening at

least a part of each of the plurality of inspection nozzle 13. The inspection hole 13a is blocked during an operation of the boiler 10. The inspection hole 13a is formed in the event of inspection of the heat transfer tube 11 after detection of a water level of the heat transfer tube 11 is completed.

[0021] The inspection nozzle 13 is located close to a passage 21 at a predetermined interval from the top surface of the passage 21.

[0022] The tube wall thickness measurement system 1 includes a data collection analysis device 2, a data display device 3 that displays data collected by the data collection analysis device 2, a cable winding device 4 that is connected to the data collection analysis device 2, a cable 5 that is a flexible tube discharged from the cable winding device 4, the ultrasonic sensor 6 for a heat transfer tube that is a sensor attached to a tip of the cable 5, a guide pipe 7 that is a guide device of the ultrasonic sensor 6 for a heat transfer tube, and an ultrasonic sensor 8 (see FIG. 3) that is attached to the inspection nozzle 13.

[0023] The ultrasonic sensor 8 attached to the inspection nozzle 13 is a sensor for detecting from the outside whether or not there is water in the inspection nozzle 13, and is different from the ultrasonic sensor 6 for a heat transfer tube which is inserted into the heat transfer tube 11.

[0024] The data collection analysis device 2 is a device to which wall thickness data of the heat transfer tube 11 measured by the ultrasonic sensor 6 for a heat transfer tube is input via the cable 5. That is, the data collection analysis device 2 includes a role in collecting and analyzing the wall thickness data of the heat transfer tube 11.

The data display device 3 is a display device (a monitor) used to display the wall thickness data of the heat transfer tube 11 which is collected by the data collection analysis device 2.

[0025] The cable 5 is inserted into the rigid heat transfer tube 11 to run in an axial direction of the heat transfer tube 11. The cable 5 is a long flexible tube formed of, for instance, a metal or plastic, and can be bent over a full length. The cable 5 contains a data signal wiring that connects the ultrasonic sensor 6 for a heat transfer

tube and the data collection analysis device 2 and a water supply hose for rotating the ultrasonic sensor 6 for a heat transfer tube with a water pressure.

The ultrasonic sensor 6 for a heat transfer tube is connected to a tip portion of the cable 5, and measures the wall thickness data of the heat transfer tube 11 by transmitting ultrasonic waves.

[0026] The guide pipe 7 guides introduction of the cable 5 and the ultrasonic sensor 6 for a heat transfer tube into the heat transfer tube 11, and is positioned inside the header 12 prior to the measurement of the wall thickness of the heat transfer tube 11. The guide pipe 7 is formed of a freely bendable tube.

The guide pipe 7 is inserted into the header 12 from the inspection hole 13a formed by opening at least a part of the inspection nozzle 13, and a tip thereof is connected to the heat transfer tube 11. In other words, the inspection hole 13a may be formed by opening at least a part of the inspection nozzle 13 to such a degree that the guide pipe 7 is inserted into the header 12 and the tip thereof is connected to the heat transfer tube 11.

[0027] As shown in FIG. 2, the boiler 10 having the heat transfer tubes 11 to be inspected is provided with a plurality of headers 12. In the following description, the boiler 10 is provided with six headers 12. That is, the boiler 10 is provided with a header 12A that is positioned at the highest position thereof, a header 12B that is positioned at the second highest position that is lower than the header 12A, a header 12C that is positioned at the third highest position that is lower than the header 12B, a header 12D that is positioned at the fourth highest position that is lower than the header 12C, a header 12E that is positioned at the fifth highest position that is lower than the header 12D, and a header 12F that is positioned at the lowest position.

Drain valves 18 are provided below the plurality of heat transfer tubes 11 connected to each of the headers. Water can be drained to a drain tank 20 via a blowing collection header 19 by opening the drain valves 18.

[0028] Next, a detailed shape of the inspection nozzle 13 will be described. In the

following description, at least a part of an internal space R2 of the inspection nozzle 13 is filled with water. FIGS. 3 to 5 are views of the header and the inspection nozzle of the embodiment of the present invention wherein (a) included in each figure are sectional view of the header in a horizontal direction perpendicular to an axis of the header, and (b) included in each figure are side elevational views of the header in an axial direction of the header.

[0029] In the embodiment shown in FIG. 3, the inspection nozzle 13 is attached to an end wall 12a that is formed on an end portion of the header 12 in the extending direction thereof. The inspection nozzle 13 and the header 12 may be joined by, for instance, welding, or may be removably attached by, for instance, via flanges. A circular through-hole 14 allowing an internal space R1 of the header 12 and the internal space R2 of the inspection nozzle 13 to communicate with each other is formed at a position of the center of the end wall 12a of the header 12.

[0030] The inspection nozzle 13 includes a bottomed cylindrical shape. That is, the inspection nozzle 13 includes a cylinder part 15 in a cylindrical shape, and a circular wall part 16. The cylinder part 15 may be formed so as to be removable from a predetermined position by, for instance, via flanges. An outer diameter of the cylinder part 15 is smaller than that of the header 12. An inner diameter of the through-hole 14 of the inspection nozzle 13 and an inner diameter of the cylinder part 15 are approximately the same.

The inspection nozzle 13 is attached to the end wall 12a of the header 12 such that an axis of the cylinder part 15 is matched with that of the header 12. In the event of the inspection of the heat transfer tube 11 after the detection of the water level of the heat transfer tube 11, the cylinder part 15 of the inspection nozzle 13 is cut or removed at a predetermined position. Thereby, the wall part 16 of the inspection nozzle 13 is separated from the header 12, and the inspection hole 13a shown in FIG. 1 is formed.

[0031] With the aforementioned constitution, when the internal space R1 of the header 12 and the internal space R2 of the inspection nozzle 13 communicate with

each other, and the internal space R1 of the header 12 can be fully filled with water. Also, the internal space R2 of the inspection nozzle 13 can be fully filled with water.

As shown in FIG. 5, in a stage immediately after the water level is reduced by drainage and the water in the internal space R2 of the inspection nozzle 13 is emptied, a space under the internal space R2 in the internal space R1 of the header 12 is still filled with water. A state of FIG. 5 is a state in which the inside of the heat transfer tube 11 connected to the header 12 is fully filled with water, whereas there is no water in the inspection nozzle 13. A method for detecting a water level of heat transfer tubes of the present invention aims to set the water level to the water level shown in FIG. 5.

[0032] The ultrasonic sensor 8 is attached to a lower outer circumferential surface 15a of the cylinder part 15 of the inspection nozzle 13. The ultrasonic sensor 8 is attached to a lowermost portion (a lower surface) of the outer circumferential surface 15a of the cylinder part 15 in a vertical direction V to transmit ultrasonic waves US1 to an upper side V1. In other words, the ultrasonic sensor 8 is installed on the inspection nozzle 13 so as to transmit the ultrasonic waves US1 upward from the lowermost portion of the cylinder part 15 toward the uppermost portion of the cylinder part 15.

The ultrasonic waves US1 transmitted from a transmitter of the ultrasonic sensor 8 to the upper side V1 are reflected at an interface between water and a metal of which the inspection nozzle 13 is formed, or an interface between water and air, and then are directed to a lower side V2. A reflected signal US2 is received by a receiver of the ultrasonic sensor 8.

[0033] Next, the method for detecting a water level of heat transfer tubes and a method for inspecting heat transfer tubes performed after the method for detecting a water level of heat transfer tubes will be described.

The detection of the water level of the heat transfer tube 11 is performed before the heat transfer tube 11 is inspected using the tube wall thickness measurement system 1, and is performed before the inspection nozzle 13 is opened.

That is, the method for detecting a water level of heat transfer tubes of the present embodiment is a method for detecting the water level of the heat transfer tube 11 without opening the inspection nozzle 13.

[0034] As shown in FIG. 7, the method for detecting a water level of heat transfer tubes includes a transmission process S1 of continuously transmitting the ultrasonic waves US1 upward from the ultrasonic sensor 8 installed on the inspection nozzle 13, a drainage process S2 of starting performing drainage from the heat transfer tube 11 and the header 12, a determination process S3 of determining whether or not a reflected signal is detected by the ultrasonic sensor 8, a drainage stoppage process S4 of stopping the drainage when the reflected signal is not detected, and an opening process S5 of opening at least a part of the inspection nozzle 13.

[0035] As an example, the inspection of the heat transfer tubes 11 is performed in order of heights of the positions of the headers 12 that are connected. In the boiler 10 shown in FIG. 2, the header 12A is positioned at the highest position. Therefore, the inspection can be performed from the heat transfer tube 11A connected to the header 12A. The inspection of the heat transfer tube 11B connected to the header 12B next to the header 12A in position is performed. Thereafter, the inspection is performed in order of the heat transfer tube 11C, the heat transfer tube 11D, the heat transfer tube 11E, and the heat transfer tube 11F.

[0036] When the header 12A positioned at the highest position is not filled with water, water is supplied using a water supply facility (not shown) of the boiler 10.

[0037] The transmission process S1 is a process of transmitting the ultrasonic waves US1 from the ultrasonic sensor 8 installed under the inspection nozzle 13 and continuing the transmission of the ultrasonic waves US1.

FIG. 6 is a graph in which the horizontal axis represents time, and the vertical axis represents a reflection time T of the ultrasonic waves which is required from the transmission to the reception of the ultrasonic waves, and which shows a time-dependent change of the reflection time T of the ultrasonic waves. The ultrasonic waves US1 transmitted from the transmitter of the ultrasonic sensor 8 on

the interface of the side close to the ultrasonic sensor are reflected at the interface between water and the metal of which the inspection nozzle 13 is formed, and the receiver of the ultrasonic sensor 8 receives the reflected signal US2.

The reflection time T from the interface between the water of the side close to the ultrasonic sensor 8 and the metal is displayed on a display device (not shown). A relation between the reflection time T and the speed of sound is calculated, and thereby a distance to the interface between the water and the metal can be calculated. Thus, the calculated distance may be displayed on the display device. The time-dependent change of FIG. 6 may be displayed on the display device.

The reflection time T may be collected and analyzed by the data collection analysis device 2, and the display device may be the data display device 3.

[0038] The drainage process S2 includes a process of opening the drain valve 18A corresponding to the heat transfer tube 11A that is an inspection object and starting drainage from the heat transfer tube 11 and the header 12.

Once the drainage is started, the water with which the header 12 is fully filled is gradually reduced as shown in FIG. 4. The internal space R2 of the inspection nozzle 13 is fully filled with water until a water surface F reaches the through-hole 14, and a change in water level does not occur, and thus the reflection time T also remains constant (a time between t0 and t1 of FIG. 6). Afterward, when the drainage continues, the inspection nozzle 13 shares the water level with the header 12, and thus the water with which the internal space R2 of the inspection nozzle 13 is filled is also gradually reduced.

When the water in the internal space R2 is reduced, the ultrasonic waves are adapted to be reflected on the interface between the water and air in the internal space R2, that is, on the water surface F. The reflection time T is gradually shortened by the reduction of the water as shown from the time t1 to a time t2 of FIG. 6.

[0039] The determination process S3 is a process of determining whether or not the reflected signal US2 is detected by the ultrasonic sensor 8. When the reflected

signal US2 is detected (YES), the detection of the reflected signal US2 continues.

The drainage stoppage process S4 is a process of stopping the drainage at a point in time when a state in which the reflected signal US2 is detected changes to a state in which the reflected signal US2 is not detected due to the drainage.

The water in the header 12 is reduced by the continuation of the drainage, and thereby the water in the internal space R2 of the inspection nozzle 13 is emptied as shown in FIG. 5. Thereby, the state in which the reflected signal US2 is detected changes to the state in which the reflected signal US2 is not detected (the time t2 of FIG. 6).

[0040] At this point in time, an operator closes the drain valve 18A corresponding to the heat transfer tube 11A. Thereby, the drainage is stopped, and the water level of the header 12 becomes the water level shown in FIG. 5. That is, while the water in the inspection nozzle 13 is emptied, the inside of the heat transfer tube 11 is fully filled with water. Thereby, even when the inspection nozzle 13 is cut, the water is not spouted. It can be ensured that the plurality of heat transfer tubes 11 connected to the lower side of the header 12 are fully filled with water.

[0041] In the opening process S5, the inspection hole 13a is formed by opening the cylinder part 15 of the inspection nozzle 13, and thereby the guide pipe 7 can be inserted into the header 12 as shown in FIG. 1.

[0042] Next, the method for inspecting heat transfer tubes performed after the method for detecting a water level of heat transfer tubes will be described.

The method for inspecting heat transfer tubes includes a guide pipe insertion process of inserting the guide pipe 7 into the header 12 from the inspection hole 13a formed in the opening process S5, an ultrasonic sensor insertion process of inserting the ultrasonic sensor 6 for a heat transfer tube via the inspection nozzle 13 and the guide pipe 7, and a heat transfer tube measuring process of measuring the wall thickness of the heat transfer tube 11.

[0043] In the ultrasonic sensor insertion process, the ultrasonic sensor 6 for a heat transfer tube is inserted from the inspection hole 13a formed in the inspection

nozzle 13, and the ultrasonic sensor 6 for a heat transfer tube is guided into the heat transfer tube 11 by the guide pipe 7.

In the heat transfer tube measuring process, the wall thickness data of the heat transfer tube 11 which is measured by the ultrasonic sensor 6 for a heat transfer tube is input to the data collection analysis device 2 via the cable 5, and the data display device 3 displays the wall thickness data of the heat transfer tube 11 which is collected by the data collection analysis device 2.

[0044] According to the embodiment, even though the water in the header 12 is sufficiently drained, the drainage can be stopped in the state in which the inside of the heat transfer tube 11 is fully filled with water. Thereby, the state in which the heat transfer tube 11 is filled with water can be easily obtained.

Since the change in the water level can be detected without removing a refractory for protecting the heat transfer tube 11, the water level can be detected at a low cost and in a short operation time.

[0045] The outer diameter of the inspection nozzle 13 is made smaller than that of the header 12, and thereby a delay of the stop of the drainage can be allowed. That is, since the reflected signal US2 is put into a state in which it is not detected, and a time is required until the water level becomes lower than an upper end of the heat transfer tube 11, the water level can be prevented from becoming lower than the upper end of the heat transfer tube 11.

[0046] The inspection nozzle 13 is located close to the passage 21 at a predetermined interval from the top surface of the passage 21, and thereby operation for the detection on the passage 21 is made possible. Thus, the operation can be safely performed.

[0047] While an embodiment of the present invention has been described in detail with reference to the drawings, the specific constitution is not limited to this embodiment, and also includes changes in design, etc. without departing from the scope of the present invention.

The inspection nozzle 13 is formed in a cylindrical shape in the embodiment.

However, it is not limited thereto and may be formed, for instance, in a square tube shape.

EXPLANATION OF REFERENCES

[0048]

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| 1 | Tube wall thickness measurement system |
| 2 | Data collection analysis device |
| 3 | Data display device |
| 4 | Cable winding device |
| 5 | Cable |
| 6 | Ultrasonic sensor for heat transfer tube |
| 7 | Guide pipe |
| 8 | Ultrasonic sensor |
| 10 | Boiler |
| 11 | Heat transfer tube |
| 12 | Header |
| 12a | End wall |
| 13 | Inspection nozzle |
| 13a | Inspection hole |
| 14 | Through-hole |
| 15 | Cylinder part |
| 16 | Wall part |
| 18 | Drain valve |
| 19 | Blowing collection header |
| 20 | Drain tank |
| 21 | Passage |
| US1 | Ultrasonic wave |
| US2 | Reflected signal |
| V | Vertical direction |