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Inventor(s)	Yang; Sungkyu et al.

Device and method for removing foreign object from heat transfer tube

Abstract

Proposed are device and method for removing a foreign object from a heat transfer tube, and the device includes a reel part configured to wind or unwind a connecting tube, a drive part, disposed adjacent to the reel part, configured to move the connecting tube in and out of a heat transfer tube, and to operate so that the connecting tube is rotatable inside the heat transfer tube, and a manipulator, disposed on an end part of the connecting tube, configured to be inserted into the heat transfer tube and to remove a foreign object placed between the heat transfer tube and an adjacent heat transfer tube, wherein the manipulator is configured to hold and transport at least a portion of the foreign object.

Inventors: **Yang; Sungkyu (Gimhae, KR), Kong; Hyunsang (Changwon, KR), Kim; Deokil (Changwon, KR), Seong; Kideok (Changwon, KR), Yang; Yoo (Busan, KR), Lee; Jaebong (Changwon, KR), Lee; Taebong (Jinju, KR)**

Applicant: **DOOSAN ENERBILITY CO., LTD.** (Changwon-si, KR)

Family ID: **1000008767771**

Assignee: **DOOSAN ENERBILITY CO., LTD. (Changwon, KR)**

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Primary Examiner: Ruppert; Eric S

Attorney, Agent or Firm: Harvest IP Law, LLP

Background/Summary

CROSS REFERENCE TO RELATED APPLICATION

(1) The present application claims priority to Korean Patent Application No. 10-2023-0012031, filed on Jan. 30, 2023, the entire contents of which are incorporated herein for all purposes by this reference.

BACKGROUND

1. Technical Field

(2) The present disclosure relate to device and method for removing a foreign object from a heat transfer tube. More particularly, the present disclosure relate to device and method for removing a foreign object from a heat transfer tube, which enables an easy removal of a foreign object located between heat transfer tubes of a steam generator.

2. Description of the Background Art

(3) Generally, a steam generator in a nuclear power plant is one of the most important core devices that generates steam required to produce electricity from steam turbines and generators.

(4) Specifically, a bundle of multiple heat transfer tubes is provided inside the steam generator. These heat transfer tubes provide a heat exchange function between primary system water, which includes radioactivity, and secondary system water, which turns a turbine. The heat transfer tubes

also function to separate the primary system water from the secondary system water.
(5) Looking at a steam generation process, primary system water is heated while the primary system water passes through a nuclear reactor and flows inside the heat transfer tube of a steam generator along the tube. Secondary system water is supplied to the outside of the heat transfer tube. The primary system water and the secondary system water exchange heat each other with the tube wall of the heat transfer tube provided therebetween. After this heat exchange, the primary system water is circulated back to the nuclear reactor along the tube of a closed circuit pipe, and the secondary system water is converted to steam.
(6) High-temperature and high-pressure radioactive water (the primary system water) flows inside the heat transfer tube, and non-radioactive water (the secondary system water) flows outside the heat transfer tube with the heat transfer tube provided between the radioactive water and the non-radioactive water. Accordingly, when the heat transfer tube is damaged, it is possible for the primary system water flowing inside the inside of the heat transfer tube to leak into the outside and become mixed with the non-radioactive water (the secondary system water), resulting in contamination. Consequently, there is a risk that an entire area where the non-radioactive water (the secondary system water) is converted to steam and supplied may become radioactively contaminated. Therefore, securing the integrity of the heat transfer tube is of utmost importance for a nuclear power plant.
(7) Conventional foreign object inspection and removal of a steam generator focused on inspecting and removing foreign objects in an upper gap of a tube plate inside a bundle of heat transfer tubes. However, it was difficult to remove foreign objects located at the upper part (a heat transfer tube support plate) of the bundle of the heat transfer tubes. In addition, with an conventional device, it may be possible to remove small foreign objects such as sludge, wire, and welding rods, but it is not easy to remove a large object, such as a bolt, etc. Therefore, the need to develop technologies for solving this problem is becoming increasingly evident.

SUMMARY

(8) Accordingly, the present disclosure has been made keeping in mind the above problems occurring in the related art. An objective of the present disclosure is to provide device and method for removing a foreign object from a heat transfer tube, especially when dealing with a large foreign object situated between heat transfer tubes.
(9) In order to achieve the above objective, according to an embodiment of the present disclosure, there is provided a device for removing a foreign object from a heat transfer tube, the device including: a reel part configured to wind or unwind a connecting tube; a drive part, disposed adjacent to the reel part, configured to move the connecting tube in and out of a heat transfer tube, and to operate so that the connecting tube is rotatable inside the heat transfer tube; and a manipulator, disposed on an end part of the connecting tube, configured to be inserted into the heat transfer tube and to remove a foreign object placed between the heat transfer tube and an adjacent heat transfer tube, wherein the manipulator is configured to hold and transport at least a portion of the foreign object.
(10) According to the embodiment of the present disclosure, the manipulator may include: a first part fixedly coupled with the end part of the connecting tube; a second part protruding upward from the first part along a portion of a circumference of the first part; and third parts protruding from two opposite ends of the second part along a circumferential direction of the first part such that an inner space is defined between the second part and the third parts.
(11) According to the embodiment of the present disclosure, the manipulator may include fourth parts protruding upward from end parts of the third parts, respectively, in a direction parallel to a protruding direction of the second part, the fourth parts protruding further upward than the second part.
(12) According to the embodiment of the present disclosure, each of the fourth parts may include: a first surface protruding further upward as a distance between the first surface and an opening

between the third parts increases; and a second surface bending and extending from an end part of the first surface, with the second surface being introduced gradually downward as a distance between the second surface and the opening between the third parts increases.
(13) According to the embodiment of the present disclosure, a first opening may be formed between the first part and the third parts, a second opening may be formed between the third parts protruding respectively from opposite sides of the second part, and a third opening may be formed between the fourth parts and the second part.
(14) According to the embodiment of the present disclosure, the foreign object may be an eye bolt, a head of the bolt may be inserted into the third opening, a body of the bolt may be inserted into the second opening, and an end part of the bolt opposite to the head of the bolt may be inserted into the first opening.
(15) According to the embodiment of the present disclosure, the fourth parts may protrude respectively from the third parts facing each other, and the fourth parts facing each other may be configured to be manipulated so that a distance between the fourth parts decreases or increases.
(16) According to the embodiment of the present disclosure, the manipulator may further include a camera disposed inside the first part, and a camera hole may be formed in a center part of a surface of the first part facing the third parts such that the camera is capable of taking a picture through the camera hole.
(17) According to the embodiment of the present disclosure, the manipulator may include: the first part fixedly coupled with the end part of the connecting tube; and grippers provided respectively on opposite sides of the first part by protruding from the first part, with a distance between the grippers increasing and decreasing as a distance between positions of the grippers and the first part increases.
(18) According to the embodiment of the present disclosure, the grippers may be configured to be manipulated such that the distance between the grippers increases and decreases.
(19) According to the embodiment of the present disclosure, the grippers may be configured to be rotatable.
(20) In addition, in order to achieve the above objective, according to another embodiment of the present disclosure, there is provided a method for removing a foreign object from a heat transfer tube, the method including: cutting at least a portion of a heat transfer tube where a foreign object is located and an adjacent heat transfer tube; moving a connecting tube upward to which a manipulator is mounted by inserting the connecting tube into the heat transfer tube; holding a portion of the foreign object by an end part of the manipulator; seating the foreign object in the manipulator by gravity by moving the manipulator; and discharging the manipulator out of the heat transfer tube.
(21) According to the another embodiment of the present disclosure, the manipulator may include: the first part fixedly coupled with an end part of the connecting tube; the second part protruding upward from the first part along a portion of a circumference of the first part; and the third parts protruding from two opposite ends of the second part along a circumferential direction of the first part such that an inner space is defined between the second part and the third parts.
(22) According to the another embodiment of the present disclosure, the manipulator may include the fourth parts protruding upward from end parts of the third parts, respectively, in a direction parallel to a protruding direction of the second part, the fourth parts protruding further upward than the second part.
(23) According to the another embodiment of the present disclosure, each of the fourth parts may include: the first surface protruding further upward as a distance between the first surface and an opening between the third parts increases; and the second surface bending and extending from an end part of the first surface, with the second surface being introduced gradually downward as a distance between the second surface and the opening between the third parts increases.
(24) According to the another embodiment of the present disclosure, the first opening may be

formed between the first part and the third parts, the second opening may be formed between the third parts protruding respectively from opposite sides of the second part, and the third opening may be formed between the fourth parts and the second part.
(25) According to the another embodiment of the present disclosure, the foreign object may be the eye bolt, the head of the bolt may be inserted into the third opening, the body of the bolt may be inserted into the second opening, and the end part of the bolt opposite to the head of the bolt may be inserted into the first opening.
(26) According to the another embodiment of the present disclosure, the fourth parts may protrude respectively from the third parts facing each other, and the fourth parts facing each other may be configured to be manipulated so that the distance between the fourth parts decreases or increases.
(27) According to the another embodiment of the present disclosure, the manipulator may further include the camera disposed inside the first part, and the camera hole may be formed in the center part of the surface of the first part facing the third parts such that the camera is capable of taking a picture through the camera hole.
(28) According to the another embodiment of the present disclosure, in the seating of the foreign object in the manipulator by gravity, the manipulator may perform at least one of an upward movement, a downward movement, and a rotation inside the heat transfer tube.
(29) According to the device for removing a foreign object from a heat transfer tube according to the present disclosure, the fourth parts facing each other can be manipulated to make a distance between the fourth parts decrease or increase, thereby adjusting the distance between the opposite sides of the fourth parts by corresponding to the size of a foreign object. In addition, after a foreign object is gripped or held by the manipulator, the distance between the fourth parts can be decreased, thereby preventing the foreign object gripped by the manipulator from escaping to the outside.
(30) According to the device for removing a foreign object from a heat transfer tube of the present disclosure, when a foreign object (a bolt) is held by the manipulator, an environment at which the foreign object is located and the position of the foreign object can be identified through the camera disposed in the manipulator so that the removal of the foreign object can be performed.
(31) According to the device for removing a foreign object from a heat transfer tube according to an embodiment of the present disclosure, the manipulator includes protruding parts on which at least a portion of a foreign object can be held through the first part, the second part, the third parts, and the fourth parts, and space in which the foreign object can be accommodated through the first opening, the second opening, and the third opening.
(32) In addition, according to the device for removing a foreign object from a heat transfer tube according to an embodiment of the present disclosure, since the manipulator can move up and down and rotate, the manipulator is configured so that a bulky foreign object such as the bolt occupies a small area in the first opening, the second opening, and the third opening described above and is more easily accommodated therein. Accordingly, a bulky foreign object such as the bolt is accommodated by the manipulator and thus can be more easily discharged through a heat transfer tube to the outside of the steam generator.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The above and other objectives, features, and other advantages of the present disclosure will be more clearly understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:
(2) FIG. **1** is a diagram illustrating a steam generator and a bundle of heat transfer tubes inside the steam generator;

(3) FIG. **2** is a diagram illustrating a device for removing a foreign object from a heat transfer tube according to an embodiment of the present disclosure;
(4) FIG. **3** is a flowchart of a method for removing a foreign object from a heat transfer tube according to the embodiment of the present disclosure;
(5) FIGS. **4**A and **4**B are diagrams illustrating a state in which at least a portion of heat transfer tubes in which a foreign object is located is cut;
(6) FIG. **5** is a diagram illustrating a state in which the device for removing a foreign object from a heat transfer tube is mounted to the steam generator;
(7) FIG. **6** is a diagram illustrating a state in which a connecting tube to which a manipulator is mounted is inserted into a heat transfer tube and is moved upward;
(8) FIGS. **7**A, **7**B, **7**C, and **7**D are diagrams illustrating a state in which a portion of a foreign object is held on an end part of the manipulator, the foreign object is seated in the manipulator, and the manipulator is discharged to the outside of a heat transfer tube; and
(9) FIGS. **8**A, **8**B, and **8**C are diagrams illustrating a manipulator according to another embodiment of the present disclosure.

DETAILED DESCRIPTION

(10) Hereinafter, exemplary embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. Terms and words used in this specification and claims should not be construed as limited to their usual or dictionary meanings. Instead, based on the principle that the inventor can appropriately define the concepts of the terms in order to explain his or her invention in the best way, the terms are required to be interpreted as meanings and concepts consistent with the technical idea of the present disclosure.
(11) FIG. **1** is a diagram illustrating a steam generator and a bundle of heat transfer tubes inside the steam generator. FIG. **2** is a diagram illustrating a device for removing a foreign object from a heat transfer tube according to an embodiment of the present disclosure. FIG. **3** is a flowchart of a method for removing a foreign object from a heat transfer tube according to the embodiment of the present disclosure. FIGS. **4**A and **4**B are diagrams illustrating a state in which at least a portion of heat transfer tubes where a foreign object is located is cut. FIG. **5** is a diagram illustrating a state in which the device for removing a foreign object from a heat transfer tube is mounted to the steam generator. FIG. **6** is a diagram illustrating a state in which a connecting tube to which a manipulator is mounted is inserted into a heat transfer tube and is moved upward. FIGS. **7**A, **7**B, **7**C, and **7**D are diagrams illustrating states in which a portion of a foreign object is held on an end part of the manipulator, the foreign object is seated in the manipulator, and the manipulator is discharged to the outside of a heat transfer tube.
(12) First, the steam generator **1** will be described hereinafter. The steam generator **1** includes an inlet **3** and an outlet **5** provided in a lower part thereof. In addition, many heat transfer tubes **10** are arranged by being connected from the center part of the steam generator **1** to the upper part thereof. A tube-supporting plate **7** is disposed on the upper side of the steam generator **1** to support the heat transfer tubes **10**. The transfer tubes **10** extends, straightly in general, from the center part of the steam generator **1** to the tube-supporting plate **7**. The heat transfer tubes **10** extend further upward than and through the tube-supporting plate **7** and are bent to be directed downward, and then extend downward. At least a part of the heat transfer tubes **10**, especially including the bent portion of the heat transfer tubes **10**, disposed on the upper side of the tube-supporting plate **7** may form a bundle **15**. Foreign objects such as an eye bolt **20** may be present between the heat transfer tubes. The foreign object removing device introduced in this disclosure is effective in removing such foreign object from the heat transfer tube **10**.
(13) A guide tube **30** may be disposed in each of the inlet **3** and outlet **5** of the steam generator. The guide tube **30** may function to guide the connecting tube **100** of the device for removing a foreign object from the heat transfer tube **10** to be described later. The guide tube **30** can guide the manipulator **400** and the connecting tube **100** to the heat transfer tube **10**. The connecting tube **100**

may be inserted into the guide tube **30**, and the guide tube **30** allows the connecting tube **100** may move toward and/or away from the heat transfer tube **10**.
(14) The device **1000** for removing a foreign object from a heat transfer tube according to the embodiment of the present disclosure includes a reel part **200**, a drive part **300**, and the manipulator **400**.
(15) The reel part **200** is configured to wind or unwind the connecting tube **100**. The reel part **200** may include a reel body **210**, a reel motor **220**, and a reel connection part **230**.
(16) The reel body **210** forms a main body on which the connecting tube **100** is wound. The reel motor **220** provides power to rotate the reel body **210** so that the connecting tube **100** is wound on the reel body **210** or unwound from the reel body **210**. The reel connection part **230** can connect the reel part **200** with the drive part **300** and is connected to the central part (i.e., a rotational center) of the reel body **210** so that the reel body **210** can easily rotate.
(17) The drive part **300** is disposed to be adjacent to the reel part **200** and configured to operate to move the connecting tube **100** in and out of the heat transfer tube **10** and to rotate the connecting tube **100** inside the heat transfer tube **10**.
(18) The drive part **300** may include an up-and-down moving part **310**, a rotation part **320**, a drive part motor **330**, a fixed plate **340**, and a protrusion part **345**.
(19) The up-and-down moving part **310** can move the connecting tube **100** upward or downward. The connecting tube **100** is extended to the outside of the reel part **200** for introducing the connecting tube **100** into the heat transfer tube **10**. On the other hand, the connecting tube **100** is wound on the reel part **200** by being moved out of and drawn back into the heat transfer tube **10**.
(20) The rotation part **320** can rotate the connecting tube **100** relative to an axial direction of the tube. Through this, the manipulator **400** to be described later can be rotated. The drive part motor **330** provides power to move the connecting tube **100** up and down or to rotate the connecting tube **100**. The fixed plate **340** may be provided to fix the device **1000** for removing a foreign object from a heat transfer tube, specifically the reel part **200** and the drive part **300**, to the steam generator **1**. The fixed plate **340** may be provided with the protrusion part **345** to be fixed to the steam generator **1**.
(21) The manipulator **400** is disposed on the end part of the connecting tube **100**, and is inserted into the heat transfer tube **10** so as to remove a foreign object disposed between heat transfer tubes **10**. The manipulator **400** is formed such that at least a portion of the foreign object is held in the manipulator **400** and is transported, which will be described further in detail.
(22) The manipulator **400** includes protruding parts configured to hold and move at least a portion of a foreign object. A foreign object is held in and fixed to the manipulator **400** and is introduced into (i.e., drawn into or brought into) the heat transfer tube **10** together with the manipulator **400** through such protruding parts. Then, the foreign object is moved in and along the transfer tube **400** and is drawn out of the heat transfer tube **10** and is finally discharged to the outside of the steam generator **1**. These movement of the foreign object is synchronized with the motion of the manipulator **400**, as the foreign object is securely held and affixed to the manipulator **400**.
(23) The manipulator **400** may include a first part **410**, a second part **420**, third parts **430**, and the fourth parts **440**.
(24) The first part **410** may be formed to be fitted over the end part of the connecting tube **100**. Specifically, the first part **410** is formed in a cylindrical shape having a central axis. The first part **410** and the and the connecting tube **100** are securely coupled to each other such that the first part **410** and the connecting tube **100** move up and down and/or rotate together. According to an embodiment, the one end of the first part **410** may have a concave part, and the connecting tube **100** is fitted into the concave part such that the manipulator **400** and the connecting tube **100** can be coupled to each other.
(25) In the assembly of the manipulator **400** and the connecting tube **100**, the direction from the connecting tube **100** toward the first part **410** along the central axis may be referred to as an upward

direction and the opposite direction may be referred to as a downward direction. The upward direction and the downward direction may be collectively referred to as a longitudinal direction. Also, a radial outward direction may be defined as a direction from the central axis toward the circumference of the first part **410**.

(26) The second part **420** may protrude upward from the other end of the first part **410** along the longitudinal direction of the first part **410**. According to an embodiment, the second part **420** may extend from only a portion of the circumference of the first part **410**. According to an embodiment, one side surface of the second part **420** is formed by straightly extended from the portion of the circumference of the first part **410** while other side surface of the second part **420** is a flat surface. The flat surface may be in a rectangular shape one short side is in contact with the first part **410**.

(27) The third parts **430** may protrude respectively from two opposite ends of the second part **420** along directions of the circumference of the first part **410** so that an inner space is defined between the second part **420** and the third parts **430**. The third parts **430** may be in a pair of two protrusions, each protruding from a long side of the rectangular shape of the second part **420** along the circumferential direction of the first part **410**. The pair of the third parts **430** may face each other.

(28) A direction in which a first one of the third parts **430** protrudes from one long side of the second part **420** may be referred to as a first circumferential direction and a direction in which a second one of the third parts **430** protrudes from the other long side of the second part **420** may be referred to as a second circumferential direction. An end of the first one of the third parts **430** in the first circumferential direction may be referred to as a first circumferential end of the third parts **430**, and an end of the second one of the third parts **430** in the second circumferential direction may be referred to as a second circumferential end of the third parts **430**. An area between the first circumferential end and the second circumferential end of the third parts **430** may be referred to as a second opening **452**.

(29) Specifically, referring to FIG. **2**, the second part **420** has a shape protruding to have an area along a portion of the circumference of the first part **410**. The third parts **430** forms a portion of a circular shape hollow inside along the circumferential direction of the second part **420** and have shapes protruding respectively from the opposite sides of the second part **420**.

(30) The third parts **430** may be positioned such that the third parts **430** and the first part **410** are spaced apart in the longitudinal direction. In other words, the downward end of the third part **430** and the upward end of the first part **410** may be spaced in the longitudinal direction.

(31) The fourth parts **440** may respectively protrude upward from an upward end of the third parts **430** in the longitudinal direction. The fourth parts **440** may protrude further upward than an upward end of the second part **420**. The fourth parts **440** may be in a pair of two protrusions, a first one of the fourth parts **420** protruding from the first one of the third parts **430** and a second one of the fourth parts **420** protruding from the second one of the third parts **430**.

(32) Referring to FIG. **2**, each of the fourth parts **440** may include a first surface **441** and a second surface **442**. Between the first surface **441** and the second surface **442**, the first surface **441** is closer to the first-circumferential-direction end of the first one of the fourth parts **440**. The first surface **441** may protrude further upward as a distance between the first surface **441** and the second opening **452** increases. That is, the first surface **441** protrudes further upward. The second surface **442** may bend and extend from the end part of the first surface **441** and may be introduced gradually downward as a distance between the second surface **442** and the second opening increase. That is, the second surface **442** is formed to be concave downward.

(33) In other words, the first surface **441** of the first one of the fourth parts **440** is formed such that a protruding length of the first one of the fourth parts **440** gradually increases in the second circumferential direction. In contrast, the second surface **442** of the first one of the fourth pats **440** is formed such that a protruding length of the first one of the fourth parts **440** gradually decreases. The second one of the fourth parts **440** has a corresponding first surface **441** and a corresponding second surface **442**.

(34) Accordingly, a protruding vertex protruding upward is formed between the first surface **441** and the second surface **442**. As described above, such protruding parts can hold a foreign object.
(35) The manipulator **400** includes a first opening **451**, the second opening **452**, and a third opening **453** which are formed therein.
(36) Specifically, the first opening **451** refers to an area formed between the first part **410** and the third parts **430**, the second opening **452** refers to an area formed between the third parts **430** protruding from the opposite sides of the second part **420**, and the third opening **453** refers to an area be formed between the fourth parts **440** and the second part **420**.
(37) Referring to FIGS. **7**A, **7**B, **7**C, and **7**D, the foreign object may be the eye bolt **20**. In this case, the head **21** of the bolt **20** may be inserted into the third opening **453**, the body **22** of the bolt **20** may be inserted into the second opening **452**, and an end part **23** of the bolt **20**, opposite to the head **21** of the bolt **20**, may be inserted into the first opening **451**.
(38) The fourth parts **440** protrude respectively from the third parts **430** facing each other, and the fourth parts **440** facing each other may be configured to be manipulated so that a distance between the fourth parts **440** is decreased or increased. For example, in FIG. **7**, before the head **21** of the bolt **20** is inserted into the third opening **453**, a distance between the fourth parts **440** may be adjusted to be increased. In addition, after the head **21** of the bolt **20** is inserted into the third opening **453**, the distance between the fourth parts **440** may be adjusted to be decreased.
(39) According to the present disclosure, since the fourth parts **440** facing each other can be manipulated to decrease or increase a distance between the fourth parts **440**, the distance between the fourth parts **440** may be adjusted according to a foreign object. In addition, after the foreign object is gripped or held, the distance between the fourth parts **440** may be decreased so that the foreign object gripped by the manipulator **400** is prevented from escaping to the outside.
(40) Meanwhile, referring to FIG. **2**, the manipulator **400** may further include a camera disposed inside the first part **410**. In addition, in the first part **410** of the manipulator **400**, a camera hole **415** may be formed in a center part of an upward end surface of the first part **410** facing the third parts **430** so that the camera can take a picture through the camera hole **415**.
(41) In the device **1000** for removing a foreign object from a heat transfer tube according to the present disclosure, when the foreign object (the bolt **20**) is gripped, an environment at which the foreign object is located and the position of the foreign object can be identified through the camera disposed in the manipulator **400**. This configuration improves the performance of the removal of the foreign object.
(42) The method for removing a foreign object from a heat transfer tube according to the embodiment of the present disclosure will be described with reference to FIG. **3**.
(43) The method for removing a foreign object from a heat transfer tube includes cutting at least a portion of a heat transfer tube **10** where a foreign object is located and an adjacent heat transfer tube **10** at S**100**, moving the connecting tube **100** upward to which the manipulator **400** is mounted by inserting the connecting tube **100** into the heat transfer tube **10** at S**200**, holding a portion of the foreign object by an end part of the manipulator **400** at S**300**, seating the foreign object in the manipulator **400** by gravity by moving the manipulator **400** at S**400**, and discharging the manipulator **400** out of the heat transfer tube **10** at S**500**.
(44) Referring to FIGS. **4**A and **4**B, in step S**100** (the cutting of at least a portion of a heat transfer tube **10** where a foreign object is located and an adjacent heat transfer tube **10** at S**100**), the at least a portion of the heat transfer tube **10** where the foreign object (the bolt **20**) is located and the adjacent heat transfer tube **10** thereto is cut to create an opening **10***a*. This is for introducing or receiving the foreign object (the bolt **20**) into the heat transfer tube **10** through an opening **10***a* of the heat transfer tube **10** and discharge the foreign object to the outside of the steam generator **1**.
(45) Referring to FIGS. **5** and **6**, in step S**200** (the upward moving of the connecting tube **100** to which the manipulator **400** is mounted by inserting the connecting tube **100** into the heat transfer tube **10**), the device **1000** is coupled to the steam generator **1**, the manipulator **400** is mounted on

the connecting tube **100**, the connecting tube **100** with the manipulator **400** mounted on is introduced into the steam generator **1**. Then, the connecting tube **100** is inserted into the heat transfer tube **10**, and the connecting tube **100** is moved upward to the upper part of the heat transfer tube **10** toward the opening **10***a*. For this operation, the drive part **300** and the reel part **200** may be operated to extend the connecting tube **100** out of the real part **200**.

(46) Referring to FIG. **7**, in step S**300** (the holding of a portion of the foreign object on the end part of the manipulator **400**), the head **21** of the bolt **20** may be held by the end part of the manipulator **400**. Specifically, the head **21** of the bolt **20** may be held by the fourth parts **440** of the manipulator **400**.

(47) In addition, in step S**400**, the foreign object is seated in the manipulator **400** by gravity by moving the manipulator **400** up and down. For example, while the head **21** of the bolt **20** is held by the fourth parts **440** of the manipulator **400**, the manipulator **400** is moved upward. Accordingly, the body **22** of the bolt **20** may be inserted through the second opening **452** into a space between the third parts **430** by gravity. In addition, by rotating the manipulator **400**, another end part of the bolt **20** may be inserted into the first opening **451**. That is, by rotating the manipulator **400**, the foreign object is seated in the manipulator **400**, and is held so as not to be moved out of the cut heat transfer tube.

(48) In the holding of a foreign object by the end part of the manipulator **400** or in the seating of a foreign object in the manipulator **400** by gravity, the manipulator **400** may perform at least one of an upward movement, a downward movement, and a rotation inside the heat transfer tube **10**.

(49) Next, the foreign object removal method includes step S**500**, which is the discharging of the manipulator **400** out of the heat transfer tube **10**. After the bolt **20** (the foreign object) is inserted into the manipulator **400**, the drive part **300** and the reel part **200** are operated so that the manipulator **400** can be discharged to the outside of the heat transfer tube **10**. Accordingly, the bolt **20** held in the manipulator **400** may be discharged to the outside of the steam generator **1** along the heat transfer tube **10**.

(50) In the device **1000** for removing a foreign object from a heat transfer tube according to the embodiment of the present disclosure, the manipulator **400** includes the protruding parts on which at least a portion of a foreign object can be held, which includes the first part **410**, the second part **420**, the third parts **430**, and the fourth parts **440**, and areas/spaces in which the foreign object can be accommodated, which includes the first opening **451**, the second opening **452**, and the third opening **453**.

(51) In addition, in the device **1000** for removing a foreign object from a heat transfer tube according to the embodiment of the present disclosure, since the manipulator **400** can move up and down and rotate, the manipulator **400** is configured such that a bulky foreign object like the bolt **20** may be seated in small areas in the first opening **451**, the second opening **452**, and the third opening **453** described above and be more easily accommodated therein.

(52) Accordingly, a bulky foreign object, such as the bolt **20**, can be accommodated by the manipulator **400** and more easily discharged to the outside of the steam generator **1** through the heat transfer tube **10**.

(53) FIGS. **8**A, **8**B, and **8**C are diagrams illustrating a manipulator according to another embodiment of the present disclosure.

(54) Referring to FIGS. **8**A, **8**B, and **8**C, the manipulator **400** of the device **1000** for removing a foreign object from a heat transfer tube according to the another embodiment of the present disclosure may include the first part **410** fitted over the end part of the connecting tube **100**, and a pair of grippers **460** provided respectively on opposite sides of the first part **410** by protruding from the first part **410**. The distance between the grippers **460** may be adjusted (i.e., may be increased and decreased) as a distance between positions of the grippers **460** and the first part **410** increases. In other words, as the distance between the grippers **460** and the first part **410** decreases, the distance between the gripers **460** may also decrease or increase.

(55) Through this shape, the grippers **460** can grip not only the head **21** of the bolt **20**, but also the body **22** of the bolt **20**. Accordingly, when it is difficult for the manipulator **400** inserted through the heat transfer tube **10** to grip the end part of the bolt **20**, the manipulator **400** according to the embodiment of the present disclosure can grip the body **22** of the bolt **20** and easily move the bolt **20**.
(56) In addition, the grippers **460** may be configured to be manipulated so that the distance between the grippers **460** increases and decreases. Additionally, the grippers **460** may be configured to be rotatable.
(57) Through this operation, the bolt **20** can be inserted into the heat transfer tube **10** by the manipulator **400** and discharged out of the heat transfer tube **10**. In addition, the body **22** of the bolt **20** is adjusted by the manipulator **400** so that the head **21** of the bolt **20** can be disposed to be located at the heat transfer tube **10**. Through this, the bolt **20** can be more easily inserted into the heat transfer tube **10**.
(58) The present disclosure has been described with reference to the embodiments illustrated in the drawings, but these embodiments are merely illustrative, and those skilled in the art will understand that various modified embodiments and equivalent other embodiments are possible therefrom. Therefore, the scope of technical protection of the present disclosure should be determined by the technical spirit of the attached claims. Also, it is noted that any one feature of an embodiment of the present disclosure described in the specification may be applied to another embodiment of the present disclosure. Similarly, the present invention encompasses any embodiment that combines features of one embodiment and features of another embodiment.

Claims

1. A device for removing a foreign object from a heat transfer tube, the device comprising: a reel part configured to wind or unwind a connecting tube; a drive part, disposed adjacent to the reel part, configured to move the connecting tube in and out of a heat transfer tube and to operate so that the connecting tube is rotatable inside the heat transfer tube; and a manipulator, disposed on an end part of the connecting tube, configured to be inserted into the heat transfer tube and to remove a foreign object placed between the heat transfer tube and an adjacent heat transfer tube, wherein the manipulator is configured to hold and transport at least a portion of the foreign object, wherein the manipulator comprises: a first part fixedly coupled with the end part of the connecting tube; a second part protruding upward from the first part along a portion of a circumference of the first part; and third parts protruding from two opposite ends of the second part along a circumferential direction of the first part such that an inner space is defined between the second part and the third parts.
2. The device of claim 1, wherein the manipulator comprises fourth parts protruding upward from end parts of the third parts, respectively, in a direction parallel to a protruding direction of the second part, the fourth parts protruding further upward than the second part.
3. The device of claim 2, wherein each of the fourth parts comprises: a first surface protruding further upward as a distance between the first surface and an opening between the third parts increases; and a second surface bending and extending from an end part of the first surface, with the second surface being introduced gradually downward as a distance between the second surface and the opening between the third parts increases.
4. The device of claim 3, wherein a first opening is formed between the first part and the third parts, a second opening is formed between the third parts protruding respectively from opposite sides of the second part, and a third opening is formed between the fourth parts and the second part.
5. The device of claim 4, wherein the foreign object is an eye bolt, a head of the bolt is inserted into the third opening, a body of the bolt is inserted into the second opening, and an end part of the bolt opposite to the head of the bolt is inserted into the first opening.

6. The device of claim 2, wherein the fourth parts protrude respectively from the third parts facing each other, and the fourth parts facing each other are configured to be manipulated so that a distance between the fourth parts decreases or increases.
7. The device of claim 1, wherein the manipulator further comprises a camera disposed inside the first part, and a camera hole is formed in a center part of a surface of the first part facing the third parts such that the camera is capable of taking a picture through the camera hole.
8. A method for removing a foreign object from a heat transfer tube, the method comprising: cutting at least a portion of a heat transfer tube where a foreign object is located and an adjacent heat transfer tube; moving a connecting tube upward to which a manipulator is mounted by inserting the connecting tube into the heat transfer tube; holding a portion of the foreign object by an end part of the manipulator; seating the foreign object in the manipulator by gravity by moving the manipulator; and discharging the manipulator out of the heat transfer tube- wherein the manipulator comprises: a first part fixedly coupled with an end part of the connecting tube; a second part protruding upward from the first part along a portion of a circumference of the first part; and third parts protruding from two opposite ends of the second part along a circumferential direction of the first part such that an inner space is defined between the second part and the third parts.
9. The method of claim 8, wherein the manipulator comprises fourth parts protruding upward from end parts of the third parts, respectively, in a direction parallel to a protruding direction of the second part, the fourth parts protruding further upward than the second part.
10. The method of claim 9, wherein each of the fourth parts comprises: a first surface protruding further upward as a distance between the first surface and an opening between the third parts increases; and a second surface bending and extending from an end part of the first surface, with the second surface being introduced gradually downward as a distance between the second surface and the opening between the third parts increases.
11. The method of claim 10, wherein a first opening is formed between the first part and the third parts, a second opening is formed between the third parts protruding respectively from opposite sides of the second part, and a third opening is formed between the fourth parts and the second part.
12. The method of claim 11, wherein the foreign object is an eye bolt, a head of the bolt is inserted into the third opening, a body of the bolt is inserted into the second opening, and an end part of the bolt opposite to the head of the bolt is inserted into the first opening.
13. The method of claim 9, wherein the fourth parts protrude respectively from the third parts facing each other, and the fourth parts facing each other are configured to be manipulated so that a distance between the fourth parts decreases or increases.
14. The method of claim 8, wherein the manipulator further comprises a camera disposed inside the first part, and a camera hole is formed in a center part of a surface of the first part facing the third parts such that the camera is capable of taking a picture through the camera hole.
15. A method for removing a foreign object from a heat transfer tube, the method comprising: cutting at least a portion of a heat transfer tube where a foreign object is located and an adjacent heat transfer tube; moving a connecting tube upward to which a manipulator is mounted by inserting the connecting tube into the heat transfer tube; holding a portion of the foreign object by an end part of the manipulator; seating the foreign object in the manipulator by gravity by moving the manipulator; and discharging the manipulator out of the heat transfer tube, wherein in the seating of the foreign object in the manipulator by gravity, the manipulator performs at least one of an upward movement, a downward movement, and a rotation inside the heat transfer tube.