(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 264 716 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
05.11.2014 Bulletin 2014/45

(51) Int Cl.:
G21F 9/00 (2006.01) ***G21F 9/28*** (2006.01)

(21) Application number: **10165462.2**

(22) Date of filing: **10.06.2010**

(54) **Decontamination method of heat exchanger and decontamination apparatus**

Dekontaminierungsverfahren für Wärmetauscher und Dekontaminierungsvorrichtung

Procédé de décontamination d’un échangeur thermique et appareil de décontamination

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

(30) Priority: **12.06.2009 JP 2009140819**

(43) Date of publication of application:
22.12.2010 Bulletin 2010/51

(73) Proprietor: **Mitsubishi Heavy Industries, Ltd.
Minato-ku
Tokyo 108-8215 (JP)**

(72) Inventors:
- **Kurokawa, Noboru
Kobe Hyogo 652-8585 (JP)**
- **Komuro, Toshiya
Kobe Hyogo 652-8585 (JP)**
- **Matsubara, Ryuichi
Hiroshima 733-8553 (JP)**
- **Yoshikawa, Masashi
Hyogo 676-8686 (JP)**
- **Fukushige, Osamu
Hyogo 652-8585 (JP)**
- **Mizuma, Hiroyuki
Hyogo 652-8585 (JP)**

(74) Representative: **Henkel, Breuer & Partner
Patentanwälte
Maximiliansplatz 21
80333 München (DE)**

(56) References cited:
DE-A1- 4 306 631
FR-A1- 2 586 322
JP-A- 2010 122 076

EP 2 264 716 B1

Description

BACKGROUND OF THE INVENTION

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger for heat-exchanging primary cooling water at an atomic power plant and also relates to a decontamination method and a decontamination apparatus for decontaminating a heat transfer tube of the heat exchanger.

BACKGROUND ART

[0002] In nuclear power generating facilities as an atomic power plant, a steam generator (a heat exchanger) for obtaining steam to drive a turbine connected to a power generator is employed. In the steam generator, a plurality of vertically-mounted and reversed-U-shaped heat transfer tubes are arranged in a cylindrical body unit. In nuclear power generating facilities, a heat exchanger tube of the steam generator is provided with a circulating system for making primary cooling water heated by a reactor pass through the heat transfer tube of the steam generator and for again returning the primary cooling water to the reactor. An inlet of secondary cooling water is provided in an intermediate portion of the body unit of the steam generator. While the primary cooling water passes through the heat transfer tube, the primary cooling water is heat-exchanged with secondary cooling water. Steam generated by this heat exchange is discharged from the uppermost portion of the body unit through a steam-water separator and a moisture separator arranged in the body unit, and is sent to the turbine. In the nuclear power plant facility, to reduce impurities included in the primary cooling water that circulates through the circulating system, a demineralizer is provided. A demineralizing system of primary cooling water supplies primary cooling water taken out from the circulating system to the demineralizer through the regenerative heat exchanger and nonregenerative heat exchanger. The primary cooling water demineralized by the demineralizer is again returned to the circulating system through the regenerative heat exchanger. In this demineralizing system also, the primary cooling water is heat exchanged by the regenerative heat exchanger and the nonregenerative heat exchanger.

[0003] In the steam generator, the heat exchanger such as the regenerative heat exchanger and the non-regenerative heat exchanger in the atomic power plant, because primary cooling water passes through the heat transfer tube that performs the heat exchange, an inner surface of the heat transfer tube is contaminated by radiation. When the heat exchanger is replaced by new one due to aged deterioration or the like, to reduce the exposure to radiation of an operator when the used heat exchanger is dismantled, it is necessary to decontaminate inside of the heat transfer tube.

[0004] As a conventional cleaning method of a tube through which radioactive fluid used in a nuclear power plant or a nuclear fuel reprocessing plant flows, there has been known a technique of sending particles, in which particle materials are mixed, into the tube (see, for example, Japanese Patent Application Laid-open No. S60-678895).

[0005] However, because the heat transfer tube of the steam generator as the heat exchanger is formed into U-shape as described above, particle materials that reach a curved portion (a bent portion) from a straight portion collide against an outer side inner wall surface of the curved portion, and the inner wall surface is excessively ground as compared with other portion. If the excessive grinding is continued, the curved portion is perforated, and radioactive secondary waste can leak outside of the heat transfer tube.

[0006] The present invention has been achieved in view of the above circumstances, and an object of the present invention is to provide a decontamination method of a heat exchanger and a decontamination apparatus capable of preventing a heat transfer tube from being perforated by partial excessive grinding.

DISCLOSURE OF INVENTION

[0007] According to an aspect of the present invention, a decontamination method of a heat exchanger for decontaminating inside of a heat transfer tube in a heat exchanger includes: a step of flowing air into the heat transfer tube, and setting a flow rate of abrasive particles to be mixed into air based on a pressure loss between an inlet side and an outlet side of the heat transfer tube; a step of calculating a permissible grinding time required until a curved portion of the heat transfer tube reaches a permissible grinding thickness based on the flow rate of the abrasive particles; and a step of flowing air being mixed with the abrasive particles into the heat transfer tube within the permissible grinding time, and backwardly flowing air mixed with the abrasive particles into the heat transfer tube.

[0008] Advantageously, in the decontamination method of a heat exchanger, at the step of flowing air being mixed with the abrasive particles into the heat transfer tube, the air with the abrasive particles is caused to flow into the heat transfer tube for a time that is a half of the permissible grinding time and then the air with the abrasive particles is caused to backwardly flow into the heat transfer tube for a time that is a half of the permissible grinding time.

[0009] According to another aspect of the present invention, a decontamination method of a heat exchanger for decontaminating inside of a heat transfer tube in a heat exchanger includes: a step of flowing air into the heat transfer tube, and setting a flow rate of abrasive particles to be mixed into air based on a pressure loss between an inlet side and an outlet side of the heat transfer tube; a step of calculating a permissible grinding time required until a curved portion of the heat transfer tube reaches a permissible grinding thickness based on the flow rate of the abrasive particles, and calculating a decontamination grinding time required until the entire heat transfer tube reaches a decontamination-accomplishment grinding amount; and a step of flowing air being mixed with the abrasive particles into the heat transfer tube and backwardly flowing the air with the abrasive particles into the heat transfer tube within the decontamination grinding time when the permissible grinding time is longer than the decontamination grinding time, and flowing the air with the abrasive particles into the heat transfer tube and backwardly flowing the air with the abrasive particles into the heat transfer tube within the permissible grinding time when the permissible grinding time is shorter than the decontamination grinding time.

[0010] Advantageously, in the decontamination method of a heat exchanger, at the step of flowing air being mixed with the abrasive particles into the heat transfer tube, the air with the abrasive particles is caused to flow into the heat transfer tube for a time that is a half of the decontamination grinding time and then the air with the abrasive particles is caused to backwardly flow into the heat transfer tube for a time that is a half of the decontamination grinding time when the permissible grinding time is longer than the decontamination grinding time, and the air with the abrasive particles is caused to flow into the heat transfer tube for a time that is a half of the permissible grinding time and then the air with the abrasive particles is caused to backwardly flow into the heat transfer tube for a time that is a half of the permissible grinding time when the permissible grinding time is shorter than the decontamination grinding time.

[0011] According to still another aspect of the present invention, a decontamination apparatus of a heat exchanger for decontaminating inside of a heat transfer tube in a heat exchanger includes: a forward inflow circuit that causes air to reach a second port from a first port of the heat transfer tube and to flow into the heat transfer tube; a backward inflow circuit that causes air to reach the first port from the second port of the heat transfer tube (304) and to flow into the heat transfer tube; a switching unit that selectively switches between the forward inflow circuit and the backward inflow circuit; an abrasive supplying unit that measures an amount of abrasive particles and mixes the abrasive particles into air that flows into the heat transfer tube; and a control unit that controls the switching unit and the abrasive supplying unit. The control unit causes the switching unit to switch between the forward inflow circuit and the backward inflow circuit, flows air into the heat transfer tube, sets a flow rate of abrasive particles to be mixed into the air based on a pressure loss between an inlet side and an outlet side of the heat transfer tube, calculates a permissible grinding time required until a curved portion of the heat transfer tube reaches a permissible grinding thickness based on the flow rate of the abrasive particles, mixes the abrasive particles into the air by the abrasive supplying unit, and causes the switching unit to switch between the forward inflow circuit and the backward inflow circuit within the permissible grinding time.

[0012] Advantageously, in the decontamination apparatus of a heat exchanger, the control unit calculates the permissible grinding time, and when a time that is a half of the permissible grinding time is elapsed after the switching unit switches the circuit to the forward inflow circuit while mixing the abrasive particles into air by the abrasive supplying unit, the switching unit switches the circuit to the backward inflow circuit.

[0013] According to still another aspect of the present invention, a decontamination apparatus of a heat exchanger for decontaminating inside of a heat transfer tube in a heat exchanger includes: a forward inflow circuit that causes air to reach a second port from a first port of the heat transfer tube and to flow into the heat transfer tube; a backward inflow circuit that causes air to reach the first port from the second port of the heat transfer tube and to flow into the heat transfer tube; a switching unit that selectively switches between the forward inflow circuit and the backward inflow circuit; an abrasive supplying unit that measures an amount of abrasive particles and mixes the abrasive particles into air that flows into the heat transfer tube; and a control unit that controls the switching unit and the abrasive supplying unit. The control unit causes the switching unit to switch between the forward inflow circuit and the backward inflow circuit, flows air into the heat transfer tube, sets a flow rate of abrasive particles to be mixed into the air based on a pressure loss between an inlet side and an outlet side of the heat transfer tube, calculates a permissible grinding time required until a curved portion of the heat transfer tube reaches a permissible grinding thickness based on the flow rate of the abrasive particles, calculates a decontamination grinding time that is required unit the entire heat transfer tube reaches the decontamination-accomplishment grinding amount, the switching unit switches between the forward inflow circuit and the backward inflow circuit within the decontamination grinding time while mixing the abrasive particles into the air by the abrasive supplying unit when the permissible grinding time is longer than the decontamination grinding time, and the switching unit switches between the forward inflow circuit and the backward inflow circuit within the permissible grinding time while mixing the abrasive particles into the air by the abrasive supplying unit when the permissible grinding time is shorter than the decontamination grinding time.

[0014] Advantageously, in the decontamination apparatus of a heat exchanger, the control unit calculates the permissible grinding time and the decontamination grinding time, the switching unit switches the circuit to the backward inflow circuit when the permissible grinding time is longer than the decontamination grinding time and when a time that is a half of the decontamination grinding time is elapsed after the switching unit switches the circuit to the forward inflow circuit while mixing the abrasive particles into the air by the abrasive supplying unit, and the switching unit switches the circuit to the backward inflow circuit when the permissible grinding time is shorter than the decontamination grinding time and when a time that is a half of the permissible grinding time is elapsed after the switching unit switches the circuit to the forward inflow circuit while mixing the abrasive particles into the air by the abrasive supplying unit.

[0015] With regard to the above statements, the other purposes, features, advantages, technical and industrial meanings of the present invention, it would be more understandable by reading the best mode(s) for carrying out the invention below, referencing attached figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 is a schematic diagram of an atomic power plant to which a decontamination method of a heat exchanger and a decontamination apparatus according to a first embodiment of the present invention are applied.

Fig. 2 is a schematic diagram of a steam generator (a heat exchanger) according to the first embodiment of the present invention.

Fig. 3 is a schematic perspective view of the decontamination apparatus of a heat exchanger according to the first embodiment of the present invention.

Fig. 4 is a schematic diagram of the decontamination apparatus of a heat exchanger according to the first embodiment of the present invention.

Fig. 5 is a schematic diagram of the decontamination apparatus of a heat exchanger according to the first embodiment of the present invention.

Fig. 6 is a schematic diagram of a point A of a curved portion of a heat transfer tube.

Fig. 7 is a flowchart of a decontaminating operation in the first embodiment of the present invention.

Fig. 8 is a flowchart of an operation (a decontamination method) of the decontamination apparatus according to the first embodiment of the present invention.

Figs. 9 depict a relationship between a grinding amount and a grinding time, for a comparison between a general example and the present invention.

Fig. 10 is a schematic diagram of measuring points in an experiment of a heat transfer tube.

Fig. 11 is a flowchart of an operation (a decontamination method) of a decontamination apparatus according to a second embodiment of the present invention.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

[0017] Exemplary embodiments of a decontamination method of a heat exchanger and a decontamination apparatus according to the present invention will be explained below in detail with reference to the accompanying drawings. The present invention is not limited to the embodiments. In addition, constituent elements in the embodiments include those that can be easily assumed by those skilled in the art or that are substantially equivalent.

[First Embodiment]

[0018] Fig. 1 depicts an atomic power plant to which a decontamination method of a heat exchanger and a decontamination apparatus according to a first embodiment of the present invention are applied. In the present embodiment, an atomic power plant 1 is a nuclear power plant facility, and a reactor 2 is a PWR (Pressurized Water Reactor).

[0019] In the atomic power plant 1, the reactor 2, a steam generator 3, a pressurizer 4, a primary cooling-water pump 5, and a regenerative heat exchanger 11 are arranged in a containment vessel 1W. A turbine 8, a steam condenser 9, and a power generator 10 are arranged outside of the containment vessel 1W. A nuclear fuel 2C is arranged in a pressure vessel of the reactor 2. The pressure vessel is filled with primary cooling water (for example, light water) C1. The primary cooling-water pump 5 and the reactor 2 are connected to each other through a primary cooling-water first supply-passage 6A. The reactor 2 and the steam generator 3 are connected to each other through a primary cooling-water second supply-passage 6B. The steam generator 3 and the primary cooling-water pump 5 are connected to each other through a primary cooling-water recovery passage 6C.

[0020] According to this configuration, the primary cooling water C1 discharged from the primary cooling-water pump 5 is supplied into the pressure vessel of the reactor 2 through the primary cooling-water first supply-passage 6A. The primary cooling water C1 is heated by thermal energy generated by atomic fission reaction of nuclear fuel 2C arranged in the pressure vessel. The heated primary cooling water C1 is supplied to the steam generator 3 through the primary cooling-water second supply-passage 6B. The primary cooling water C1 passes through heat transfer tubes 304 of the steam generator 3 and then the primary cooling water C1 flows out from the steam generator 3, returns to the primary cooling-water pump 5 through the primary cooling-water recovery passage 6C, and is again discharged into the pressure vessel of the reactor 2 from the primary cooling-water first supply-passage 6A.

[0021] The steam generator 3 includes the heat transfer tubes 304 in plural, secondary cooling water C2 outside of the heat transfer tubes 304 is heated and boiled by the primary cooling water C1 flowing in the heat transfer tubes 304, and high temperature and high pressure steam of the secondary cooling water C2 is produced. The steam generator 3 and the turbine 8 are connected to each other through a steam supply passage 7S. The steam condenser 9 and the steam generator 3 are connected to each other through a secondary cooling-water recovery passage 7R. According to this configuration, the high temperature and high pressure steam of the secondary cooling water C2 produced by the steam generator 3 is supplied to the turbine 8 through the steam supply passage 7S and the steam drives the turbine 8. Electricity is generated by the power generator 10 connected to a drive shaft of the turbine 8. The secondary cooling water C2 after it drove the turbine 8 becomes liquid in the steam condenser 9, and it is again sent to the steam generator 3 through the secondary cooling-water recovery passage 7R.

[0022] The reactor 2 is a pressurized water reactor, and the pressurizer 4 is connected to the primary cooling-water second supply-passage 6B. The pressurizer 4 applies a pressure to the primary cooling water C1 in the primary cooling-water second supply-passage 6B. According to the structure, the primary cooling water C1 is not boiled even if it is heated by the thermal energy generated by the atomic fission reaction of the nuclear fuel 2C, and the primary cooling water C1 circulates through the reactor 2 and its cooling system in its liquid phase state. The cooling system of the reactor 2 includes the primary cooling-water pump 5, the primary cooling-water first supply-passage 6A, the primary cooling-water second supply-passage 6B, the steam generator 3, and the primary cooling-water recovery passage 6C. The primary cooling water C1 flows through the cooling system of the reactor 2.

[0023] The atomic power plant 1 includes a demineralizer 16 to reduce impurities included in the primary cooling water C1. The demineralizer 16 includes a first demineralizer 16A and a second demineralizer 16B. The demineralizer 16 is arranged outside of the containment vessel 1W. The first demineralizer 16A is a cooling-water hotbed demineralizer, and the second demineralizer 16B is a cooling-water cation demineralizer. The primary cooling water C1 taken out from an inlet side (an upstream side) of the primary cooling-water pump 5 is supplied from the cooling system of the reactor 2 to the demineralizer 16, and the primary cooling water C1 is subjected to the demineralizing processing, and the demineralized primary cooling water C1 is returned to an outlet side (a downstream side) of the primary cooling-water pump 5.

[0024] A demineralizing processing system of the primary cooling water C1 includes a primary cooling-water taking-out passage 13A, a regenerative heat exchanger 11, a primary cooling-water passage 13B, a nonregenerative heat exchanger 12, a primary cooling-water passage 13C, the demineralizer 16, a primary cooling-water passage 13D, a volume control tank 14, and primary cooling-water returning passages 13E and 13F. The regenerative heat exchanger 11 and the primary cooling-water recovery passage 6C constituting the cooling system of the reactor 2 are connected to each other through the primary cooling-water taking-out passage 13A. The regenerative heat exchanger 11 and the nonregenerative heat exchanger 12 are connected to each other through the primary cooling-water passage 13B. The nonregenerative heat exchanger 12 and the demineralizer 16 are connected to each other through the primary cooling-water passage 13C. The demineralizer 16 and the volume control tank 14 are connected to each other through the primary cooling-water passage 13D. The volume control tank 14 and the regenerative heat exchanger 11 are connected to each other through the primary cooling-water returning passage 13E. The regenerative heat exchanger 11 and the primary cooling-water first supply-passage 6A are connected to each other through the primary cooling-water returning passage 13F. The primary cooling-water returning passage 13E includes a charging pump 15.

[0025] The primary cooling water C1 is taken out from the primary cooling-water taking-out passage 13A, that is, from the inlet side (the upstream side) of the primary cooling-water pump 5. The primary cooling water C1 taken out from the cooling system of the reactor 2 is introduced into the regenerative heat exchanger 11 and then it is introduced into the demineralizer 16 through the primary cooling-water passage 13B, the nonregenerative heat exchanger 12, and the primary cooling-water passage 13C, and the primary cooling water C1 is subjected to the demineralizing processing. The demineralized primary cooling water C1 is temporarily stored in the volume control tank 14 through the primary cooling-water passage 13D. Thereafter, the primary cooling water C1 is sent to the regenerative heat exchanger 11 by the charging pump 15 provided in the primary cooling-water returning passage 13E. The primary cooling water C1 that passed through the regenerative heat exchanger 11 is returned to the primary cooling-water first supply-passage 6A, that is, the outlet side (the downstream side) of the primary cooling-water pump 5 through the primary cooling-water returning passage 13F.

[0026] In the present embodiment, the heat exchanger to which the decontamination method and the decontamination apparatus are applied is the steam generator 3, the regenerative heat exchanger 11, and the nonregenerative heat exchanger 12 through which the primary cooling water C1 filled in the pressure vessel of the reactor 2 passes. In the present embodiment, the steam generator 3 is described as a main subject. Fig. 2 depicts the steam generator (the heat exchanger) according to the present embodiment.

[0027] As shown in Fig. 2, the steam generator 3 extends in a vertical direction, and is of a tightly closed hollow cylindrical shape. The steam generator 3 includes a body unit 301 having an upper half and a lower half, and a diameter of the lower half is slightly smaller than that of the upper half. A cylindrical tube-group outer cylinder 302 is provided in the lower half of the body unit 301 at a predetermined distance between the tube-group outer cylinder 302 and an inner wall surface of the body unit 301. The tube-group outer cylinder 302 extends to a tube plate 303. A lower end of the tube-group outer cylinder 302 is arranged at a lower portion in the lower half of the body unit 301. A heat transfer tube group 304A including the plurality of reversed-U-shaped heat transfer tubes 304 is provided in the tube-group outer cylinder 302. Each of the heat transfer tubes 304 is arranged such that the U-shaped curved portion thereof is oriented upward, and an end of the heat transfer tube 304 oriented downward is supported by the tube plate 303, and an intermediate portion of the heat transfer tube 304 is supported by a plurality of tube support plates 305. A large number of through holes (not shown) are formed in the tube support plates 305, and the heat transfer tubes 304 pass through the through holes in a non-contact state.

[0028] A water chamber 306 is provided in a lower end of the body unit 301. The water chamber 306 is divided into an inlet chamber 306A and an outlet chamber 306B by a division wall 307. A first port 304a of each of the heat transfer tubes 304 is in communication with the inlet chamber 306A, and a second port 304b of each of the heat transfer tubes 304 is in communication with the outlet chamber 306B. An inlet nozzle 306AA that is in communication with outside of the body unit 301 is formed in the inlet chamber 306A, and an outlet nozzle 306BB that is in communication with outside of the body unit 301 is formed in the outlet chamber 306B. The primary cooling-water second supply-passage 6B to which the primary cooling water C1 is sent from the reactor 2 is connected to the inlet nozzle 306AA. The primary cooling-water recovery passage 6C through which the primary cooling water C1 after it has been exchanged is sent to the reactor 2 is connected to the outlet nozzle 306BB.

[0029] A steam-water separator 308 that separates fed water into steam and hot water, and a moisture separator 309 that reduces moisture of the separated steam and brings the steam into a state close to dry steam are provided in the upper half of the body unit 301. A feedwater tube 310 for feeding the secondary cooling water C2 into the body unit 301 from outside is inserted between the steam-water separator 308 and the heat transfer tube group 304A. A steam discharge port 311 is formed in an upper end of the body unit 301. A feedwater passage 312 is provided in the lower half of the body unit 301. The feedwater passage 312 downwardly flows the secondary cooling water C2 fed into the body unit 301 from the feedwater tube 310 between the body unit 301 and the tube-group outer cylinder 302, and returns the secondary cooling water C2 at the tube plate 303, and flows the secondary cooling water C2 upward along the heat transfer tube group 304A. The steam supply passage 7S for sending steam to the turbine 8 is connected to the steam discharge port 311. The secondary cooling-water recovery passage 7R for supplying secondary cooling water C2 obtained by cooling steam used in the turbine 8 by the steam condenser 9 is connected to the feedwater tube 310.

[0030] According to the steam generator 3, the primary cooling water C1 heated by the reactor 2 is sent to the inlet chamber 306A, the primary cooling water C1 circulates through the large number of heat transfer tubes 304, and reaches the outlet chamber 306B. The secondary cooling water C2 cooled by the steam condenser 9 is sent to the feedwater tube 310, the secondary cooling water C2 passes through the feedwater passage 312 in the body unit 301 and rises along the heat transfer tube group 304A. At that time, heat exchange is performed between the high pressure and high temperature primary cooling water C1 and the secondary cooling water C2. The cooled primary cooling water C1 is returned to the reactor 2 from the outlet chamber 306B. The secondary cooling water C2 heat exchanged with the high pressure and high temperature primary cooling water C1 rises in the body unit 301, and is separated into steam and hot water by the steam-water separator 308. The moisture of the separated steam is reduced by the moisture separator 309 and then sent to the turbine 8.

[0031] In the steam generator 3, the upper end of the heat transfer tube group 304A including the plurality of heat transfer tubes 304 is formed into a hemispherical shape by the reversed-U-shaped curved portion of the heat transfer tube 304. Specifically, one of the heat transfer tubes 304 with the curved portion having the smallest curvature is arranged at a center portion of the heat transfer tube group 304A, and heat transfer tubes 304 with larger curved portions having greater curvatures are arranged toward outside of the hemispherical shape in sequence. By superposing the arranged tubes and reducing the outer heat transfer tubes 304 in sequence, the upper end of the heat transfer tube group 304A is formed into the hemispherical shape.

[0032] As described above, in the steam generator 3, because the primary cooling water C1 passes through the heat transfer tube 304 that performs the heat exchange, the inner surface of the heat transfer tube 304 is contaminated by radiation. When the steam generator 3 is replaced by new one due to aged deterioration or the like, to reduce the exposure to radiation of an operator when the used steam generator 3 is dismantled, it is necessary to decontaminate inside of the heat transfer tube 304.

[0033] The decontamination apparatus according to the present embodiment is described below. Figs. 3 to 5 depict the decontamination apparatus of the heat exchanger according to the present embodiment. A decontamination apparatus 100 includes a forward inflow circuit 101, a backward inflow circuit 102, an abrasive circulating unit 103, circuit connecting units 104, and a control unit 105.

[0034] As indicated by solid arrows in Figs. 4 and 5, the forward inflow circuit 101 flows air mixed with abrasive particles from the first port 304a of the heat transfer tube 304 to the second port 304b, and then flows it into the heat transfer tube 304. As shown in Fig. 3, the forward inflow circuit 101 includes a compressor 106, a supply passage 107, an abrasive supplying unit 108, a switching unit 109, a first supply/recovery passage 110, a second supply/recovery passage 111, a recovery passage 112, and a recovering and separating unit 113.

[0035] The compressor 106 compresses air to high pressure. Air compressed by the compressor 106 is sent out as jet stream through the supply passage 107 connected to the compressor 106. The abrasive supplying unit 108 is interposed in an intermediate portion of the supply passage 107. The abrasive supplying unit 108 is formed as a hopper for example, a predetermined amount of abrasive particles is supplied to the supply passage 107 and is mixed into the jet stream of air. In the present embodiment, particles of alumina (aluminum oxide) are mainly used as the abrasive particles, and an average particle diameter thereof is 0.5 millimeter. Other examples of the abrasive particles are ceramic particles and metal (such as stainless or iron) particles. The supply passage 107 is connected to the first supply/recovery passage 110 through the switching unit 109. The switching unit 109 is described later. The first supply/recovery passage 110 is connected to the first port 304a of the heat transfer tube 304, and includes a pressure gage 110A. The second supply/recovery passage 111 is connected to the second port 304b of the heat transfer tube 304 and the second supply/recovery passage 111 includes a pressure gage 111A. The second supply/recovery passage 111 is connected to the recovery passage 112 through the switching unit 109. The recovery passage 112 is connected to the recovering and separating unit 113. Air that passed through the heat transfer tube 304 passes through the recovery passage 112. The recovering and separating unit 113 recovers abrasive particles mixed into air that passes through the recovery passage 112, and recovers secondary waste that has been ground by the abrasive particles, and separates the abrasive particles and the secondary waste from each other. The separated secondary waste is stored in the recovering and separating unit 113, and the separated abrasive particles are returned to the abrasive supplying unit 108. Jet stream air after the abrasive particles and the secondary waste are recovered therefrom is discharged from the recovering and separating unit 113 through a blower (not shown).

[0036] That is, the forward inflow circuit 101 sends the jet stream air compressed by the compressor 106 to the supply passage 107, the switching unit 109, the first supply/recovery passage 110, the heat transfer tube 304, the second supply/recovery passage 111, the switching unit 109, the recovery passage 112, and the recovering and separating unit 113 in this order, thereby flowing air in which the abrasive particles are mixed by the abrasive supplying unit 108 to the second port 304b from the first port 304a of the heat transfer tube 304, and flowing the air into the heat transfer tube 304.

[0037] As shown with dashed lines in Figs. 4 and 5, the backward inflow circuit 102 flows air mixed with the abrasive particles to the first port 304a from the second port 304b of the heat transfer tube 304, and flows the air into the heat transfer tube 304. Like the forward inflow circuit 101, the backward inflow circuit 102 includes the compressor 106, the supply passage 107, the abrasive supplying unit 108, the switching unit 109, the first supply/recovery passage 110, the second supply/recovery passage 111, the recovery passage 112, and the recovering and separating unit 113.

[0038] The switching unit 109 selectively switches such that the switching unit 109 connects the supply passage 107 to the first supply/recovery passage 110, connects the recovery passage 112 to the second supply/recovery passage 111, connects the supply passage 107 to the second supply/recovery passage 111, and connects the recovery passage 112 to the first supply/recovery passage 110. A circuit in which the supply passage 107 is connected to the first supply/recovery passage 110 and the recovery passage 112 is connected to the second supply/recovery passage 111 by the switching unit 109 is the forward inflow circuit 101. A circuit in which the supply passage 107 is connected to the second supply/recovery passage 111 and the recovery passage 112 is connected to the first supply/recovery passage 110 by the switching unit 109 is the backward inflow circuit 102.

[0039] That is, the backward inflow circuit 102 sends the jet stream air compressed by the compressor 106 to the supply passage 107, the switching unit 109, the second supply/recovery passage 111, the heat transfer tube 304, the first supply/recovery passage 110, the switching unit 109, the recovery passage 112, and the recovering and separating unit 113 in this order, thereby flowing air in which the abrasive particles are mixed by the abrasive supplying unit 108 to the first port 304a from the second port 304b of the heat transfer tube 304 and flowing the air into the heat transfer tube 304.

[0040] The abrasive circulating unit 103 includes the abrasive supplying unit 108 and the recovering and separating unit 113. The abrasive supplying unit 108 supplies a predetermined amount of abrasive particles to the supply passage 107 and mixes the abrasive particles into the jet stream air. The recovering and separating unit 113 recovers the abrasive particles and the secondary waste mixed in the air that passes through the recovery passage 112, separates the abrasive particles and the secondary waste from each other, stores the secondary waste, and returns the abrasive particles to the abrasive supplying unit 108. That is, the abrasive circulating unit 103 is commonly provided in the forward inflow circuit 101 and the backward inflow circuit 102. The abrasive circulating unit 103 recovers abrasive particles coming from the downstream side of the jet stream air, returns the recovered abrasive particles to the upstream side of the jet stream air, and circulates and uses the abrasive particles.

[0041] The abrasive circulating unit 103 does not need to be provided. In this case, as shown in Fig. 5, a recovering unit 120 that recovers and stores abrasive particles and secondary waste mixed in the air that passes through the recovery passage 112 is provided in the recovery passage 112 instead of the recovering and separating unit 113.

[0042] As shown in Fig. 3, the circuit connecting units

104 are provided on the inlet chamber 306A and the outlet chamber 306B of the steam generator 3, and the circuit connecting units 104 connect the first supply/recovery passage 110 and the second supply/recovery passage 111 of the circuits 101 and 102 to a port of any of the plurality of heat transfer tubes 304. The circuit connecting units 104 include a connection nozzle 114.

[0043] The connection nozzle 114 forms a connecting portion that connects the first supply/recovery passage 110 and the second supply/recovery passage 111 to the ports of the heat transfer tubes 304. It is preferable that the connection nozzle 114 connects the first supply/recovery passage 110 and the second supply/recovery passage 111 to one of the heat transfer tubes 304 in a one-to-one relationship. The connection nozzle 114 is provided on supporting members (not shown) arranged on the inlet chamber 306A and the outlet chamber 306B, and the connection nozzle 114 is connected to and separated from the port of the heat transfer tube 304 by an actuator (not shown).

[0044] The control unit 105 is constituted by a microcomputer. The control unit 105 includes a storage unit 105a, a computing unit 105b, and a time register 105c. The compressor 106, the abrasive supplying unit 108, the switching unit 109, the pressure gages 110A and 111A, and the circuit connecting unit 104 are connected to the control unit 105. The compressor 106, the abrasive supplying unit 108, the switching unit 109, and the circuit connecting unit 104 are subject to centralized control by the control unit 105 according to programs and data stored in the storage unit 105a in advance, a grinding time calculated by the computing unit 105b, and a time measured by the time register 105c.

[0045] The storage unit 105a is constituted by a RAM or a ROM, and programs and data are stored therein. The programs and data stored in the storage unit 105a are for driving the compressor 106, the abrasive supplying unit 108, the switching unit 109, and the circuit connecting unit 104. Particularly, data used by the computing unit 105b that calculates the grinding time suitable for each of the heat transfer tubes 304 is stored in the storage unit 105a.

[0046] The computing unit 105b calculates a permissible grinding time (tA) required until the curved portion (a point A: see Fig. 6) of the heat transfer tube 304 reaches its permissible grinding thickness (thinnest grinding thickness within a range such that a hole is not generated) in forward inflow and backward inflow based on the data stored in the storage unit 105a, and based on pressures obtained by the pressure gages 110A and 111A by flowing air into the forward inflow circuit 101 or the backward inflow circuit 102. The forward inflow is to flow air mixed with the abrasive particles into the forward inflow circuit 101, and the backward inflow is to flow the air mixed with the abrasive particles into the backward inflow circuit 102.

[0047] Specifically, the computing unit 105b measures pressure losses in the inflow circuits 101 and 102 by an inlet-side pressure and an outlet-side pressure of the inflow circuits 101 and 102 obtained from the pressure gages 110A and 111A. The computing unit 105b calculates the flow velocity (V) of air from the measured pressure losses. When calculating the flow velocity (V) of air, an inner diameter of the heat transfer tube 304 is set constant, a length of the heat transfer tube 304 is preset for each of the heat transfer tubes 304 corresponding to a position to which the connection nozzle 114 is connected by the circuit connecting unit 104, and the data is stored in the storage unit 105a. The computing unit 105b sets a mixture ratio [mass of abrasive particles/mass of air] (C) suitable for grinding in accordance with the flow velocity (V). The mixture ratio (C) is obtained by an experiment carried out in advance, and is stored in the storage unit 105a. The mass of abrasive particles and diameters of the abrasive particles are set constant, and are stored in the storage unit 105a. The computing unit 105b sets a flow rate (Qp) of the abrasive particles based on the flow velocity (V) of air, the mass of the abrasive particles, and the diameters of the abrasive particles. The computing unit 105b calculates a permissible grinding time (tA[min]) required until the curved portion (the point A: see Fig. 6) of the heat transfer tube 304 reaches its permissible grinding thickness (thinnest grinding thickness within a range such that a hole is not generated) in forward inflow and backward inflow based on the following equation 1.

(Equation 1)

$$WA = b \cdot Qp \cdot \sin\alpha \cdot tA$$

[0048] In the equation 1, WA represents a grinding amount [mm], b represents a constant obtained by an experiment carried out in advance and stored in the storage unit 105a, α represents a collision angle of the abrasive particles, and this is an angle formed between an inflow direction of the abrasive particles and a tangent of the inner wall surface at the point A where the abrasive particles that flow into the heat transfer tube 304 in a direction of the arrow in Fig. 6 collide against the curved portion and the curved portion is most excessively ground. The angle (α) is preset for each of the heat transfer tubes 304 corresponding to a position to which the connection nozzle 114 is connected by the circuit connecting unit 104, and the angle is stored in the storage unit 105a. That is, the permissible grinding time (tA) required until the curved portion (the point A) of the heat transfer tube 304 is ground by a grinding amount (WA) corresponding to the permissible grinding thickness in forward inflow and backward inflow is calculated by the equation 1.

[0049] The time register 105c measures the decontaminating time (the grinding time) in the decontamination apparatus 100.

[0050] The decontamination method that is an operation of the decontamination apparatus 100 is described with reference to flowcharts in Figs. 7 and 8.

[0051] In the present embodiment, when the heat exchanger is replaced by new one due to aged deterioration or the like, to prevent an operator from being irradiated with radiation when the used heat exchanger is dismantled, the inside of the heat transfer tube is decontaminated, and the decontamination apparatus and the decontamination method are applied.

[0052] When a decontaminating operation is performed, a greenhouse 118 (see Fig. 3) is first installed to cover the side of the water chamber 306 of the used steam generator 3 (Step S1). According to this configuration, a periphery of the water chamber 306 is isolated to prevent the radiation from being scattered.

[0053] Next, the decontamination apparatus 100 outside of the steam generator 3 is prepared (Step S2). That is, the decontamination apparatus 100 is installed outside of the greenhouse 118. Specifically, the supply passage 107 is connected to the compressor 106, the abrasive supplying unit 108 is connected to the supply passage 107, and the supply passage 107 is connected to the switching unit 109. The recovery passage 112 is connected to the recovering and separating unit 113, and the recovery passage 112 is connected to the switching unit 109. The first supply/recovery passage 110 and the second supply/recovery passage 111 are connected to the switching unit 109.

[0054] Next, a manhole of the water chamber 306 of the steam generator 3 is opened, and the inlet nozzle 306AA of the inlet chamber 306A and the outlet nozzle 306BB of the outlet chamber 306B are opened (Step S3).

[0055] Next, the decontamination apparatus 100 inside of the steam generator 3 is prepared (Step S4). That is, the circuit connecting units 104 are installed for the inlet chamber 306A and the outlet chamber 306B. At that time, an operator wears radiation protective clothing to prevent the operator from being exposed to radiation.

[0056] Next, the decontamination is performed (Step S5). At Step S5, the decontamination apparatus 100 according to the present embodiment is operated, and the decontamination method is applied.

[0057] Finally, when the decontamination is completed, the decontamination apparatus 100 is dismounted (Step S6). Because the inside of the heat transfer tube 304 is decontaminated after Step S6, the steam generator 3 can be dismantled.

[0058] The operation (the decontamination method) of the decontamination apparatus 100 at Step S5 is shown in the flowchart of the operation (the decontamination method) of the decontamination apparatus in Fig. 8. First, the control unit 105 connects the first supply/recovery passage 110 to the first port 304a of desired one of the heat transfer tubes 304, and connects the second supply/recovery passage 111 to the second port 304b of desired one of the heat transfer tubes 304 by the circuit connecting unit 104 (Step S11). At the same time, the control unit 105 causes the switching unit 109 to switch the circuit to the forward inflow circuit 101 (Step S12).

[0059] Next, the control unit 105 operates the compressor 106 to draw air, measures pressures on the side of the inlet (on the side of the first port 304a) and on the side of the outlet (on the side of the second port 304b) of the heat transfer tube 304, and sets the flow rate (Qp) of the abrasive particles based on a pressure loss between the inlet side and the outlet side of the heat transfer tube 304 (Step S13).

[0060] Next, the control unit 105 calculates the permissible grinding time (tA) required until the curved portion (the point A) of the heat transfer tube 304 reaches its permissible grinding thickness in forward inflow and backward inflow (Step 14).

[0061] Next, the control unit 105 equalizes the forward inflow time (tA forward), the backward inflow time (tA backward), and the permissible grinding time (tA/2), mixes the abrasive particles into air, switches the switching unit 109, and performs a grinding operation in forward inflow and backward inflow (Step S15).

[0062] That is, in the forward inflow circuit 101, air mixed with the abrasive particles is caused to reach the second port 304b from the first port 304a of the heat transfer tube 304 and to flow into the heat transfer tube 304, and the inside of the heat transfer tube 304 is decontaminated. When the forward inflow time (tA forward) that is the permissible grinding time (tA/2) is elapsed, the control unit 105 causes the switching unit 109 to switch the circuit to the backward inflow circuit 102. According to this configuration, in the backward inflow circuit 102, the air mixed with the abrasive particles is caused to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304, and the inside of the heat transfer tube 304 is continuously decontaminated. When the backward inflow time (tA backward) that is the remaining permissible grinding time (tA/2) is elapsed, the control unit 105 stops the inflow of air, and the decontaminating operation is completed.

[0063] Steps S11 to S15 are repeatedly performed until the decontaminating operation of all of the heat transfer tubes 304 of the steam generator 3 is completed in a state where the circuit connecting unit 104 connects the first supply/recovery passage 110 and the second supply/recovery passage 111 to the next heat transfer tube 304.

[0064] At Step S12, the switching unit 109 can switch the circuit to the backward inflow circuit 102. In this case, at Step S15, in the backward inflow circuit 102, air mixed with the abrasive particles is caused to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304, and when the backward inflow time (tA backward) that is the permissible grinding time (tA/2) is elapsed, the switching unit 109 switches the circuit to the forward inflow circuit 101, and in the forward inflow circuit 101, air mixed with the abrasive particles is caused to reach the second port 304b from the first port 304a of the heat transfer tube 304 and the air is caused to flow into the heat transfer tube

304, and when the forward inflow time (tA forward) that is the remaining permissible grinding time (tA/2) is elapsed, the inflow of air is stopped, and the decontaminating operation is completed.

[0065] In this manner, the decontamination method of the first embodiment includes a step of flowing air into the heat transfer tube 304 and setting a flow rate of the abrasive particles that are mixed into the air based on a pressure loss between the inlet side and the outlet side of the heat transfer tube 304, a step of calculating the permissible grinding time (tA) required until the curved portion (the point A) of the heat transfer tube 304 reaches its permissible grinding thickness, and a step of flowing, into the heat transfer tube 304, the air mixed with the abrasive particles for a time that is a half of the permissible grinding time (tA) and then backwardly flowing the air mixed with the abrasive particles into the heat transfer tube 304 for a time that is a half of the permissible grinding time (tA).

[0066] According to this decontamination method, the permissible grinding time (tA) required until the curved portion (the point A) reaches its permissible grinding thickness is calculated, and the inside of the heat transfer tube 304 is ground by the forward inflow and the backward inflow for a time that is a half of the permissible grinding time (tA) each. As a result, because a case that the curved portion is excessively ground is avoided, it is possible to prevent the heat transfer tube 304 from being perforated by partial excessive grinding.

[0067] The permissible grinding thickness of the curved portion (the point A) is the thinnest thickness within a range such that the curved portion is not perforated, and when the curved portion is ground to this grinding thickness, other inside portions of the heat transfer tube 304 are ground to such an extent that the other inside portions are appropriately decontaminated.

[0068] According to the decontamination method of the first embodiment, the forward inflow circuit 101 and the backward inflow circuit 102 are switched by the switching unit 109, and the second port 304b of the heat transfer tube 304 is switched from downstream to upstream of the jet stream air. As shown in Fig. 9(a) for example, in all of grinding steps of a general example, when air mixed with the abrasive particles is caused to reach the second port 304b from the first port 304a of the heat transfer tube 304 and to flow into the heat transfer tube 304, and when the decontamination is performed until the upstream side (on the side of the first port 304a of the heat transfer tube 304) is caused to reach the target grinding amount, the downstream side (on the side of the second port 304b of the heat transfer tube 304) is excessively ground and a large amount of secondary waste is generated. On the other hand, in all of the grinding steps of the first embodiment shown in Fig. 9(b), a switching operation is performed such that air mixed with the abrasive particles in mid-course is caused to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304. According to this configuration, the decontamination effect can be equalized over the entire length of the heat transfer tube 304 without excessively grinding the heat transfer tube 304, and the decontamination time can be shortened.

[0069] The decontamination method according to the first embodiment includes a step of recovering the abrasive particles coming from the downstream side of the jet stream air when the air mixed with the abrasive particles is caused to flow into the heat transfer tube 304, and a step of returning the recovered abrasive particles to the upstream side of the jet stream air. According to this decontamination method, it is possible to further suppress the amount of secondary waste generated, by using the abrasive particles coming from the downstream side of the jet stream air again for the decontamination.

[0070] In the decontamination method according to the first embodiment, at the step of flowing the air mixed with the abrasive particles into the heat transfer tube 304, air mixed with the abrasive particles can be made to flow into the heat transfer tube 304 within the permissible grinding time (tA), and air mixed with the abrasive particles can be made to flow into the heat transfer tube 304 backwardly. That is, the decontamination is not limited to a case that a time (tA/2) that is a half of the permissible grinding time (tA) is spent for each of the forward inflow time (tA forward) and the backward inflow time (tA backward), the forward inflow time (tA forward) and the backward inflow time (tA backward) can slightly be different from each other, and effects described above can be obtained.

[0071] The decontamination apparatus 100 according to the first embodiment includes the forward inflow circuit 101 that causes air to reach the second port 304b from the first port 304a of the heat transfer tube 304 and to flow into the heat transfer tube 304, the backward inflow circuit 102 that causes air to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304, the switching unit 109 switches between the forward inflow circuit 101 and the backward inflow circuit 102, the abrasive supplying unit 108 that measures the abrasive particles and mixes the abrasive particles into air flowing into the heat transfer tube 304 while measuring the amount of the abrasive particles, and the control unit 105 for controlling the switching unit 109 and the abrasive supplying unit 108. The control unit 105 causes the switching unit 109 to switch between the forward inflow circuit and the backward inflow circuit, flows air into the heat transfer tube 304, sets the flow rate of the abrasive particles to be mixed into air based on the pressure loss between the inlet side and the outlet side of the heat transfer tube 304, calculates the permissible grinding time (tA) required until the curved portion (the point A) of the heat transfer tube 304 reaches the permissible grinding thickness based on the flow rate of the abrasive particles, mixes the abrasive particles into air by the abrasive supplying unit 108, and when a time that is a half of the permissible grinding time (tA) is elapsed after the switching unit 109 switches the circuit to the forward inflow circuit 101, the switching unit 109 switches the circuit to the backward inflow circuit 102.

[0072] According to the decontamination apparatus 100, the decontamination method described above can be performed, a case that the curved portion is excessively ground is avoided, and it is possible to prevent the heat transfer tube 304 from being perforated by partial excessive grinding. Further, the decontamination effect can be equalized over the entire length of the heat transfer tube 304, and the decontamination time can be shortened.

[0073] The decontamination apparatus 100 according to the first embodiment includes the abrasive circulating unit 103 that recovers abrasive particles coming from the downstream side of the jet stream air and that returns the recovered abrasive particles to the upstream side of the jet stream air. According to the decontamination apparatus 100, it is possible to further suppress the amount of secondary waste generated, by using the abrasive particles coming from the downstream side of the jet stream air again for the decontamination.

[0074] According to the decontamination apparatus 100 of the first embodiment, the control unit 105 can calculate the permissible grinding time (tA), mix the abrasive particles into air by the abrasive supplying unit 108, and causes the switching unit 109 to switch between the forward inflow circuit 101 and the backward inflow circuit 102 within the permissible grinding time (tA). That is, the present invention is not limited to the case that time (tA/2) that is a half of the permissible grinding time (tA) is spent for each of the forward inflow time (tA forward) and the backward inflow time (tA backward), the forward inflow time (tA forward) and the backward inflow time (tA backward) can be slightly different from each other, and effects described above can be obtained.

[Second Embodiment]

[0075] In a second embodiment, a decontamination method that is an operation of the decontamination apparatus 100 is different from that of the first embodiment. Therefore, in the second embodiment described below, only the control unit 105 that is a configuration concerning the operation of the decontamination apparatus 100 is described, and like constituent elements of the first embodiment are denoted by like reference numerals and explanations thereof will be omitted.

[0076] The control unit 105 is constituted by a microcomputer. The control unit 105 includes the storage unit 105a, the computing unit 105b, and the time register 105c. The compressor 106, the abrasive supplying unit 108, the switching unit 109, the pressure gages 110A and 111A, and the circuit connecting unit 104 are connected to the control unit 105. The compressor 106, the abrasive supplying unit 108, the switching unit 109, and the circuit connecting unit 104 are subject to centralized control by the control unit 105 according to programs and data stored in the storage unit 105a in advance, a grinding time calculated by the computing unit 105b, and a time measured by the time register 105c.

[0077] The storage unit 105a is constituted by a RAM or a ROM, and programs and data are stored therein. The programs and data stored in the storage unit 105a are for driving the compressor 106, the abrasive supplying unit 108, the switching unit 109, and the circuit connecting unit 104. Particularly, data used by the computing unit 105b that calculates the grinding time suitable for each of the heat transfer tubes 304 is stored in the storage unit 105a.

[0078] The computing unit 105b calculates a permissible grinding time (tA) required until the curved portion (the point A: see Fig. 6) of the heat transfer tube 304 reaches its permissible grinding thickness (thinnest grinding thickness within a range such that a hole is not generated) in forward inflow and backward inflow based on the data stored in the storage unit 105a, and based on pressures obtained by the pressure gages 110A and 111A by flowing air into the forward inflow circuit 101 or the backward inflow circuit 102. The forward inflow is to flow air mixed with abrasive particles into the forward inflow circuit 101, and the backward inflow is to flow the air mixed with abrasive particles into the backward inflow circuit 102.

[0079] Specifically, the computing unit 105b measures pressure losses in the inflow circuits 101 and 102 by an inlet-side pressure and an outlet-side pressure of the inflow circuits 101 and 102 obtained from the pressure gages 110A and 111A. The computing unit 105b calculates the flow velocity (V) of air from the measured pressure losses. When calculating the flow velocity (V) of air, an inner diameter of the heat transfer tube 304 is set constant, a length of the heat transfer tube 304 is preset for each of the heat transfer tubes 304 corresponding to a position to which the connection nozzle 114 is connected by the circuit connecting unit 104, and the data is stored in the storage unit 105a. The computing unit 105b sets a mixture ratio [mass of abrasive particles/mass of air] (C) suitable for grinding in accordance with the flow velocity (V). The mixture ratio (C) is obtained by an experiment carried out in advance, and is stored in the storage unit 105a. The mass of abrasive particles and diameters of the abrasive particles are set constant, and are stored in the storage unit 105a. The computing unit 105b sets a flow rate (Qp) of the abrasive particles based on the flow velocity (V) of air, the mass of the abrasive particles, and the diameters of the abrasive particles. The computing unit 105b calculates a permissible grinding time (tA[min]) required until the curved portion (the point A: see Fig. 6) of the heat transfer tube 304 reaches its permissible grinding thickness (thinnest grinding thickness within a range such that a hole is not generated) in forward inflow and backward inflow based on the following equation 1.

(Equation 1)

$$WA = b \cdot Qp \cdot \sin\alpha \cdot tA$$

[0080] In the equation 1, WA represents a grinding amount [mm], b represents a constant obtained by an experiment carried out in advance, and stored in the storage unit 105a, α represents a collision angle of the abrasive particles, and this is an angle formed between the inflow direction of the abrasive particles and a tangent of the inner wall surface at the point A where the abrasive particles that flow into the heat transfer tube 304 in the direction of the arrow in Fig. 6 collide against the curved portion and the curved portion is most excessively ground. The angle (α) is preset for each of the heat transfer tubes 304 corresponding to a position to which the connection nozzle 114 is connected by the circuit connecting unit 104, and the angle is stored in the storage unit 105a. That is, the permissible grinding time (tA) required until the curved portion (the point A) of the heat transfer tube 304 is ground by a grinding amount (WA) corresponding to the permissible grinding thickness in forward inflow and backward inflow is calculated by the equation 1.

[0081] Further, the computing unit 105b calculates a decontamination grinding time (2t) required until the entire heat transfer tube 304 reaches the decontamination-accomplishment grinding amount (W) at which the decontamination of the entire heat transfer tube 304 is achieved in the forward inflow and backward inflow based on the data stored in the storage unit 105a, and based on pressures obtained by the pressure gages 110A and 111A by flowing air into the forward inflow circuit 101 or the backward inflow circuit 102.

[0082] Specifically, the computing unit 105b measures a pressure loss in the inflow circuits 101 and 102 from inlet side pressure and outlet side pressure of the inflow circuits 101 and 102 obtained from the pressure gages 110A and 111A. The computing unit 105b calculates the flow rate (V) of air from the measured pressure loss. When calculating the flow rate (V) of air, an inner diameter of the heat transfer tube 304 is set constant, the length of the heat transfer tube 304 is present for each of the heat transfer tubes 304 corresponding to a position to which the connection nozzle 114 is connected by the circuit connecting unit 104, and the data is stored in the storage unit 105a. The computing unit 105b sets a mixture ratio [mass of abrasive particles/mass of air] (C) suitable for grinding in accordance with the flow velocity (V). The mixture ratio (C) is obtained by an experiment carried out in advance, and is stored in the storage unit 105a. The mass of abrasive particles and diameters of the abrasive particles are set constant, and are stored in the storage unit 105a. The computing unit 105b calculates a decontamination grinding time (2t[min]) required until the entire heat transfer tube 304 reaches the decontamination-accomplishment grinding amount (W) at which the decontamination of the entire heat transfer tube 304 is achieved.

(Equation 2)

$$W = a \cdot V^{n1} \cdot C^{n2} \cdot 2t$$

[0083] In the equation 2, W represents a grinding amount [μm]. Further, a, n1, and n2 represent regression constants, and they are based on the grinding amount obtained by measuring a pressure in an experiment carried out in advance at measuring points P1 to P9 in the heat transfer tube 304 as shown in Fig. 10, and the regression constants are stored in the storage unit 105a. That is, the decontamination grinding time (2t) required until the entire heat transfer tube 304 reaches the decontamination-accomplishment grinding amount (W) at which the decontamination of the entire heat transfer tube 304 is achieved is calculated by the equation 2.

[0084] The time register 105c measures the decontaminating time (the grinding time) in the decontamination apparatus 100.

[0085] The decontamination method that is the operation of the decontamination apparatus 100 is described with reference to a flowchart in Fig. 11.

[0086] In the present embodiment, when the heat exchanger is replaced by new one due to aged deterioration or the like, to prevent an operator from being irradiated with radiation when the used heat exchanger is dismantled, the inside of the heat transfer tube is decontaminated, and the decontamination apparatus and the decontamination method are applied.

[0087] The decontaminating operation is shown in the flowchart of the decontaminating operation of Fig. 7 described in the first embodiment. The operation (the decontamination method) of the decontamination apparatus 100 at Step S5 in Fig. 7 is shown in the flowchart of the operation (the decontamination method) of the decontamination apparatus in Fig. 11. The control unit 105 connects the first supply/recovery passage 110 to a first port 304a of desired one of the heat transfer tubes 304, and connects the second supply/recovery passage 111 to the second port 304b of desired one of the heat transfer tubes 304 by the circuit connecting unit 104 (Step S21). At the same time, the control unit 105 causes the switching unit 109 to switch the circuit to the forward inflow circuit 101 (Step S22).

[0088] Next, the control unit 105 operates the compressor 106 to flow air in, measures pressures on the inlet side (on the side of the first port 304a) and on the outlet side (on the side of the second port 304b) of the heat transfer tube 304, and sets the flow rate (Qp) of the abrasive particles based on a pressure loss between the inlet side and the outlet side of the heat transfer tube 304 (Step S23).

[0089] Next, the control unit 105 calculates a permissible grinding time (tA) required until the curved portion (the point A) of the heat transfer tube 304 reaches the permissible grinding thickness in the forward inflow and the backward inflow (Step S24).

[0090] Next, the control unit 105 calculates the decontamination grinding time (2t) required until the entire heat transfer tube 304 reaches the decontamination-accomplishment grinding amount (W) in the forward inflow and the backward inflow (Step S25).

[0091] Next, the permissible grinding time (tA) and the decontamination grinding time (2t) are compared with each other, and when the permissible grinding time (tA) is longer than the decontamination grinding time (2t) (YES at Step S26), the control unit 105 equalizes the forward inflow time (t forward) and backward inflow time (t backward), and the decontamination grinding time (2t/2), and mixes abrasive particles into air, switches the switching unit 109, and performs a grinding operation by forward inflow and backward inflow (Step S27).

[0092] That is, in the forward inflow circuit 101, air mixed with the abrasive particles is caused to reach the second port 304b from the first port 304a of the heat transfer tube 304 and to flow into the heat transfer tube 304, and the inside of the heat transfer tube 304 is decontaminated. When the forward inflow time (t forward) that is the decontamination grinding time (2t/2) is elapsed, the control unit 105 causes the switching unit 109 to switch the circuit to the backward inflow circuit 102. According to this configuration, in the backward inflow circuit 102, air mixed with the abrasive particles is caused to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304, and the inside of the heat transfer tube 304 is continuously decontaminated. When the backward inflow time (t backward) that is the remaining decontamination grinding time (2t/2) is elapsed, the control unit 105 stops the inflow of air, and completes the decontaminating operation.

[0093] Meanwhile, at Step S26, when the permissible grinding time (tA) is shorter than the decontamination grinding time (2t) (NO at Step S26), the control unit 105 equalizes the forward inflow time (tA forward), the backward inflow time (tA backward), and the permissible grinding time (tA/2), mixes the abrasive particles into air, switches the switching unit 109, and performs the grinding operation by forward inflow and backward inflow (Step S28).

[0094] That is, in the forward inflow circuit 101, air mixed with the abrasive particles is caused to reach the second port 304b from the first port 304a of the heat transfer tube 304 and to flow into the heat transfer tube 304, and the inside of the heat transfer tube 304 is decontaminated. When the forward inflow time (tA forward) that is the permissible grinding time (tA/2) is elapsed, the control unit 105 causes the switching unit 109 to switch the circuit to the backward inflow circuit 102. With this configuration, in the backward inflow circuit 102, air mixed with the abrasive particles is caused to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304, and the inside of the heat transfer tube 304 is continuously decontaminated. When the backward inflow time (tA backward) that is the remaining permissible grinding time (tA/2) is elapsed, the control unit 105 stops the inflow of air, and completes the decontaminating operation.

[0095] Steps S21 to S28 are repeatedly performed until the decontaminating operation of all of the heat transfer tubes 304 of the steam generator 3 is completed while connecting the first supply/recovery passage 110 and the second supply/recovery passage 111 to the next heat transfer tube 304 by the circuit connecting unit 104.

[0096] At Step S22, the switching unit 109 can switch the circuit to the backward inflow circuit 102. In this case, at Step S27, in the backward inflow circuit 102, air mixed with the abrasive particles is caused to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304, and when the backward inflow time (t backward) that is the decontamination grinding time (2t/2) is elapsed, the switching unit 109 switches the circuit to the forward inflow circuit 101, and in the forward inflow circuit 101, air mixed with the abrasive particles is caused to reach the second port 304b from the first port 304a of the heat transfer tube 304 and to flow into the heat transfer tube 304, and when the forward inflow time (t forward) that is the remaining decontamination grinding time (2t/2) is elapsed, the inflow of air is stopped, and the decontaminating operation is completed. At Step S28, in the backward inflow circuit 102, air mixed with the abrasive particles is caused to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304, and when the backward inflow time (tA backward) that is the permissible grinding time (tA/2) is elapsed, the switching unit 109 switches the circuit to the forward inflow circuit 101, and in the forward inflow circuit 101, air mixed with the abrasive particles is caused to reach the second port 304b from the first port 304a of the heat transfer tube 304 and to flow into the heat transfer tube 304, and when the forward inflow time (t forward) that is the remaining permissible grinding time (tA/2) is elapsed, the inflow of air is stopped, and the decontaminating operation is completed.

[0097] The decontamination method according to the second embodiment includes a step of flowing air into the heat transfer tube 304, and setting a flow rate of abrasive particles to be mixed into the air based on a pressure loss between the inlet side and the outlet side of the heat transfer tube 304, a step of calculating the permissible grinding time (tA) required until the curved portion (the point A) of the heat transfer tube 304 reaches the permissible grinding thickness, and calculating the decontamination grinding time (2t) required until the entire heat transfer tube 304 reaches the decontamination-accomplishment grinding amount (W), and a step of flowing air mixed with the abrasive particles into the heat transfer tube 304 for a time that is a half of the decontamination grinding time (2t) and then backwardly flowing air mixed with the abrasive particles into the heat transfer tube 304 for a time that is a half of the decontamination grinding time (2t) when the permissible grinding time (tA) is longer than the decontamination grinding time (2t), and flowing air mixed with the abrasive particles into the heat transfer tube 304 for a time that is a half of the permissible grinding time (tA) and then backwardly flowing air mixed with the abrasive particles into the heat transfer tube 304 backwardly for a time that is a half of the permissible grinding time (tA) when the permissible grinding time (tA) is shorter than the decontamination grinding time (2t).

[0098] According to this decontamination method, the permissible grinding time (tA) and the decontamination grinding time (2t) are calculated, and when the permissible grinding time (tA) is longer than the decontamination grinding time (2t) and the entire heat transfer tube 304 reaches the decontamination-accomplishment grinding amount (W) before the curved portion (the point A) reaches the permissible grinding thickness, a higher priority is given to the decontamination grinding time (2t), and the inside of the heat transfer tube 304 is ground by the forward inflow and backward inflow for the time that is a half of the decontamination grinding time (2t) each. When the permissible grinding time (tA) is shorter than the decontamination grinding time (2t), a higher priority is given to the permissible grinding time (tA), and the inside of the heat transfer tube 304 is ground by the forward inflow and backward inflow for the time that is a half of the permissible grinding time (tA) each. As a result, a case that the curved portion is excessively ground can be avoided, and it is possible to prevent the heat transfer tube 304 from being perforated by partial excessive grinding. Further, the decontamination can be performed within the shortest decontaminating time.

[0099] The grinding thickness permitted for the curved portion (the point A) is the thinnest grinding thickness within a range such that the curved portion is not perforated, and when the curved portion is ground into this grinding thickness, other inside portions of the heat transfer tube 304 are ground to such an extent that the other inside portions are appropriately decontaminated. Therefore, even if a higher priority is given to the permissible grinding time (tA) when the permissible grinding time (tA) is shorter than the decontamination grinding time (2t), the entire heat transfer tube 304 can appropriately be decontaminated.

[0100] According to the decontamination method of the second embodiment, the forward inflow circuit 101 and the backward inflow circuit 102 are switched by the switching unit 109, and the second port 304b of the heat transfer tube 304 is switched from the downstream to the upstream of the jet stream air. As shown in Fig. 9(a) for example, in all of the grinding steps of the general example, when air mixed with the abrasive particles is caused to reach the second port 304b from the first port 304a of the heat transfer tube 304 and to flow into the heat transfer tube 304, and when the decontamination is performed until the upstream side (on the side of the first port 304a of the heat transfer tube 304) is caused to reach the target grinding amount, the downstream side (on the side of the second port 304b of the heat transfer tube 304) is excessively ground and a large amount of secondary waste is generated. On the other hand, in all of the grinding steps of the first embodiment shown in Fig. 9(b), a switching operation is performed such that air mixed with the abrasive particles in mid-course is caused to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304. According to this configuration, the decontamination effect can be equalized over the entire length of the heat transfer tube 304 without excessively grinding the heat transfer tube 304, and the decontamination time can be shortened.

[0101] The decontamination method according to the second embodiment includes a step of recovering the abrasive particles coming from the downstream side of the jet stream air when the air mixed with the abrasive particles is caused to flow into the heat transfer tube 304, and a step of returning the recovered abrasive particles to the upstream side of the jet stream air. According to this decontamination method, it is possible to further suppress the amount of secondary waste generated, by using the abrasive particles coming from the downstream side of the jet stream air again for the decontamination.

[0102] In the decontamination method according to the second embodiment, the step of flowing air mixed with the abrasive particles into the heat transfer tube 304 can be a step of flowing air mixed with the abrasive particles into the heat transfer tube 304 and backwardly flowing air mixed with the abrasive particles into the heat transfer tube 304 within the decontamination grinding time (2t) when the permissible grinding time (tA) is longer than the decontamination grinding time (2t), and flowing air mixed with the abrasive particles into the heat transfer tube 304 and backwardly flowing air mixed with the abrasive particles into the heat transfer tube 304 within the permissible grinding time (tA) when the permissible grinding time (tA) is shorter than the decontamination grinding time (2t). That is, the present invention is not limited to a case that the decontaminating operation is performed while using a time that is a half (tA/2) of the permissible grinding time (tA) as the forward inflow time (tA forward) and the backward inflow time (tA backward), or not limited to a case that the decontaminating operation is performed while using a time that is a half (2t/2) of the decontamination grinding time (2t) as the forward inflow time (tA forward) and the backward inflow time (tA backward). The forward inflow time (tA forward, t forward) and the backward inflow time (tA backward, t backward) can slightly be different from each other, and effects described above can be obtained.

[0103] The decontamination apparatus 100 according to the second embodiment described above includes the forward inflow circuit 101 that causes air to reach the second port 304b from the first port 304a of the heat transfer tube 304 and to flow into the heat transfer tube 304, the backward inflow circuit 102 that causes air to reach the first port 304a from the second port 304b of the heat transfer tube 304 and to flow into the heat transfer tube 304, the switching unit 109 that selectively switches between the forward inflow circuit 101 and the backward inflow circuit 102, the abrasive supplying unit 108 that mixes abrasive particles into air flowing into the heat transfer tube 304 while measuring the amount of abrasive particles, and the control unit 105 that controls the switching unit 109 and the abrasive supplying unit 108. The control unit 105 causes the switching unit 109 to switch between the forward inflow circuit and the backward inflow circuit, flows air into the heat transfer tube 304, sets the flow rate of the abrasive particles that are mixed into air based on the pressure loss between the inlet side and the outlet side of the heat transfer tube 304, calculates the permissible grinding time (tA) required until the curved portion (the point A) of the heat transfer tube 304 reaches the permissible grinding thickness based on the flow rate of the abrasive particles, and calculates the decontamination grinding time (2t) required until the entire heat transfer tube 304 reaches the decontamination-accomplishment grinding amount (W). When the permissible grinding time (tA) is longer than the decontamination grinding time (2t), and when a time that is a half of the decontamination grinding time (2t) is elapsed after the switching unit 109 switches the circuit to the forward inflow circuit 101 while mixing the abrasive particles into air by the abrasive supplying unit 108, the switching unit 109 switches the circuit to the backward inflow circuit 102. When the permissible grinding time (tA) is shorter than the decontamination grinding time (2t), and when a time that is a half of the permissible grinding time (tA) is elapsed after the switching unit 109 switches the circuit to the forward inflow circuit 101 while missing the abrasive particles into the air by the abrasive supplying unit 108, the switching unit 109 switches the circuit to the backward inflow circuit 102.

[0104] According to the decontamination apparatus 100, the decontamination method can be performed, a case that the curved portion is excessively ground is avoided, and it is possible to prevent the heat transfer tube 304 from being perforated by partial excessive grinding. Further, the decontamination can be performed within the shortest decontamination time. Further, the decontamination effect can be equalized over the entire length of the heat transfer tube 304, and the decontamination time can be shortened.

[0105] The decontamination apparatus 100 according to the second embodiment includes the abrasive circulating unit 103 that recovers abrasive particles coming from the downstream side of the jet stream air and returns the recovered abrasive particles to the upstream side of the jet stream air. According to the decontamination apparatus 100, it is possible to further suppress the amount of secondary waste generated, by using the abrasive particles coming from the downstream side of the jet stream air again for the decontamination.

[0106] According to the decontamination apparatus 100 of the second embodiment, when the permissible grinding time (tA) is longer than the decontamination grinding time (2t), the control unit 105 can cause the switching unit 109 to switch between the forward inflow circuit 101 and the backward inflow circuit 102 within the decontamination grinding time (tA) while mixing the abrasive particles into air by the abrasive supplying unit 108. When the permissible grinding time (tA) is shorter than the decontamination grinding time (2t), the control unit 105 can cause the switching unit 109 to switch between the forward inflow circuit 101 and the backward inflow circuit 102 within the permissible grinding thickness (2t) while mixing the abrasive particles into air by the abrasive supplying unit 108. That is, the present invention is not limited to the case that the decontaminating operation is performed while using a time that is a half (tA/2) of the permissible grinding time (tA) as the forward inflow time (tA forward) and the backward inflow time (tA backward), or not limited to a case that the decontaminating operation is performed while using a time that is a half (2t/2) of the decontamination grinding time (2t) as the forward inflow time (tA forward) and the backward inflow time (tA backward). The forward inflow time (tA forward, t forward) and the backward inflow time (tA backward, t backward) can slightly be different from each other, and effects described above can be obtained.

[0107] As described above, the decontamination method of a heat exchanger and the decontamination apparatus according to the present invention are suitable to prevent a heat transfer tube from being perforated by partial excessive grinding.

Claims

1. A decontamination method of a heat exchanger for decontaminating inside of a heat transfer tube (304) in a heat exchanger (3; 11; 12), the method comprising:

a step of flowing air into the heat transfer tube (304), and setting a flow rate (Qp) of abrasive particles to be mixed into air based on a pressure loss between an inlet (304a) side and an outlet (304b) side of the heat transfer tube (304);
a step of calculating a permissible grinding time (tA) required until a curved portion (A) of the heat transfer tube (304) reaches a permissible grinding thickness based on the flow rate (Qp) of the abrasive particles; and
a step of flowing air being mixed with the abrasive particles into the heat transfer tube (304) within the permissible grinding time (tA), and backwardly flowing air mixed with the abrasive

particles into the heat transfer tube (304).

2. The decontamination method of a heat exchanger according to claim 1, wherein at the step of flowing air being mixed with the abrasive particles into the heat transfer tube (304), the air with the abrasive particles is caused to flow into the heat transfer tube (304) for a time that is a half of the permissible grinding time (tA) and then the air with the abrasive particles is caused to backwardly flow into the heat transfer tube (304) for a time that is a half of the permissible grinding time (tA).

3. A decontamination method of a heat exchanger for decontaminating inside of a heat transfer tube (304) in a heat exchanger (3; 11; 12), the method comprising:

   a step of flowing air into the heat transfer tube (304), and setting a flow rate (Qp) of abrasive particles to be mixed into air based on a pressure loss between an inlet (304a) side and an outlet (304b) side of the heat transfer tube (304);
   a step of calculating a permissible grinding time (tA) required until a curved portion (A) of the heat transfer tube (304) reaches a permissible grinding thickness based on the flow rate (Qp) of the abrasive particles, and calculating a decontamination grinding time (2t) required until the entire heat transfer tube (304) reaches a decontamination-accomplishment grinding amount (W); and
   a step of flowing air being mixed with the abrasive particles into the heat transfer tube (304) and backwardly flowing the air with the abrasive particles into the heat transfer tube (304) within the decontamination grinding time (2t) when the permissible grinding time (tA) is longer than the decontamination grinding time (2t), and flowing the air with the abrasive particles into the heat transfer tube (304) and backwardly flowing the air with the abrasive particles into the heat transfer tube (304) within the permissible grinding time (tA) when the permissible grinding time (tA) is shorter than the decontamination grinding time (2t).

4. The decontamination method of a heat exchanger according to claim 3, wherein at the step of flowing air being mixed with the abrasive particles into the heat transfer tube (304), the air with the abrasive particles is caused to flow into the heat transfer tube (304) for a time that is a half of the decontamination grinding time (2t) and then the air with the abrasive particles is caused to backwardly flow into the heat transfer tube (304) for a time that is a half of the decontamination grinding time (2t) when the permissible grinding time (tA) is longer than the decontamination grinding time (2t), and the air with the abrasive particles is caused to flow into the heat transfer tube (304) for a time that is a half of the permissible grinding time (tA) and then the air with the abrasive particles is caused to backwardly flow into the heat transfer tube (304) for a time that is a half of the permissible grinding time (tA) when the permissible grinding time (tA) is shorter than the decontamination grinding time (2t).

5. A decontamination apparatus of a heat exchanger for decontaminating inside of a heat transfer tube (304) in a heat exchanger (3; 11; 12), the decontamination apparatus comprising:

   a forward inflow circuit (101) that causes air to reach a second port (304b) from a first port (304a) of the heat transfer tube (304) and to flow into the heat transfer tube (304);
   a backward inflow circuit (102) that causes air to reach the first port (304a) from the second port (304b) of the heat transfer tube (304) and to flow into the heat transfer tube (304);
   a switching unit (109) that selectively switches between the forward inflow circuit (101) and the backward inflow circuit (102);
   an abrasive supplying unit (108) that measures an amount of abrasive particles and mixes the abrasive particles into air that flows into the heat transfer tube (304); and
   a control unit (105) that controls the switching unit (109) and the abrasive supplying unit (109), wherein
   the control unit (105) causes the switching unit (109) to switch between the forward inflow circuit (101) and the backward inflow circuit (102), flows air into the heat transfer tube (304), sets a flow rate (Qp) of abrasive particles to be mixed into the air based on a pressure loss between an inlet (304a) side and an outlet (304b) side of the heat transfer tube (304), calculates a permissible grinding time (tA) required until a curved portion (A) of the heat transfer tube (304) reaches a permissible grinding thickness based on the flow rate (Qp) of the abrasive particles, mixes the abrasive particles into the air by the abrasive supplying unit (109), and causes the switching unit (109) to switch between the forward inflow circuit (101) and the backward inflow circuit (102) within the permissible grinding time (tA).

6. The decontamination apparatus of a heat exchanger according to claim 5, wherein the control unit (105) calculates the permissible grinding time (tA), and when a time that is a half of the permissible grinding time (tA) is elapsed after the switching unit (109) switches the circuit to the forward inflow circuit (101)

while mixing the abrasive particles into air by the abrasive supplying unit (109), the switching unit (109) switches the circuit to the backward inflow circuit (102).

7. A decontamination apparatus of a heat exchanger for decontaminating inside of a heat transfer tube (304) in a heat exchanger (3; 11; 12), the decontamination apparatus comprising:

a forward inflow circuit (101) that causes air to reach a second port (304b) from a first port (304a) of the heat transfer tube (304) and to flow into the heat transfer tube (304);
a backward inflow circuit (102) that causes air to reach the first port (304a) from the second port (304b) of the heat transfer tube (304) and to flow into the heat transfer tube (304);
a switching unit (109) that selectively switches between the forward inflow circuit (101) and the backward inflow circuit (102);
an abrasive supplying unit (109) that measures an amount of abrasive particles and mixes the abrasive particles into air that flows into the heat transfer tube (304); and
a control unit (105) that controls the switching unit (109) and the abrasive supplying unit (109), wherein
the control unit (105) causes the switching unit (109) to switch between the forward inflow circuit (101) and the backward inflow circuit (102), flows air into the heat transfer tube (304), sets a flow rate (Qp) of abrasive particles to be mixed into the air based on a pressure loss between an inlet (304a) side and an outlet (304b) side of the heat transfer tube (304), calculates a permissible grinding time (tA) required until a curved portion (A) of the heat transfer tube (304) reaches a permissible grinding thickness based on the flow rate (Qp) of the abrasive particles, calculates a decontamination grinding time (2t) that is required unit the entire heat transfer tube (304) reaches the decontamination-accomplishment grinding amount (W), the switching unit (109) switches between the forward inflow circuit (101) and the backward inflow circuit (102) within the decontamination grinding time (2t) while mixing the abrasive particles into the air by the abrasive supplying unit (109) when the permissible grinding time (tA) is longer than the decontamination grinding time (2t), and the switching unit (109) switches between the forward inflow circuit (101) and the backward inflow circuit (102) within the permissible grinding time (tA) while mixing the abrasive particles into the air by the abrasive supplying unit (109) when the permissible grinding time (tA) is shorter than the decontamination grinding time (2t).

8. The decontamination apparatus of a heat exchanger according to claim 7, wherein the control unit (105) calculates the permissible grinding time (tA) and the decontamination grinding time (2t), the switching unit (109) switches the circuit to the backward inflow circuit (102) when the permissible grinding time (tA) is longer than the decontamination grinding time (2t) and when a time that is a half of the decontamination grinding time (2t) is elapsed after the switching unit (109) switches the circuit to the forward inflow circuit (101) while mixing the abrasive particles into the air by the abrasive supplying unit (109), and the switching unit (109) switches the circuit to the backward inflow circuit (102) when the permissible grinding time (tA) is shorter than the decontamination grinding time (2t) and when a time that is a half of the permissible grinding time (tA) is elapsed after the switching unit (109) switches the circuit to the forward inflow circuit (101) while mixing the abrasive particles into the air by the abrasive supplying unit (109).

Patentansprüche

1. Dekontaminationsverfahren für einen Wärmetauscher zum Dekontaminieren des Inneren eines Wärmetransferrohres (304) in einem Wärmetauscher (3;11;12), wobei das Verfahren umfasst:

einen Schritt des Einströmens von Luft in das Wärmetransferrohr (304), sowie des Einstellens einer Strömungsmenge (Qp) von in die Luft einzumischenden Schleifpartikeln, basierend auf einem Druckverlust zwischen einer Einlassseite (304a) und einer Auslassseite (304b) des Wärmetransferrohres (304),
einen Schritt des Berechnens einer bis zum Erreichen einer zulässigen Schleifdicke eines gekrümmten Abschnitts (A) des Wärmetransferrohres (304) benötigten zulässigen Schleifzeit (tA), basierend auf der Strömungsmenge (Qp) der Schleifpartikel, und
einen Schritt des Einströmens von Luft im Gemisch mit den Schleifpartikeln in das Wärmetransferrohr (304) innerhalb der zulässigen Schleifzeit (tA), sowie des Einströmens von Luft im Gemisch mit den Schleifpartikeln in Rückwärtsrichtung in das Wärmetransferrohr (304).

2. Dekontaminationsverfahren für einen Wärmetauscher nach Anspruch 1, wobei bei dem Schritt des Einströmens von Luft im Gemisch mit den Schleifpartikeln in das Wärmetransferrohr (304) die die Schleifpartikel enthaltende Luft für eine Zeit in das Wärmetransferrohr (304) einströmen gelassen wird, die der Hälfte der zulässigen Schleifzeit (tA) entspricht, und die die Schleifpartikel enthaltende Luft anschließend in Rückwärtsrichtung für eine Zeit in

das Wärmetransferrohr (304) einströmen gelassen wird, die der Hälfte der zulässigen Schleifzeit (tA) entspricht.

3. Dekontaminationsverfahren für einen Wärmetauscher zum Dekontaminieren des Inneren eines Wärmetransferrohres (304) in einem Wärmetauscher (3;11;12), wobei das Verfahren umfasst:

einen Schritt des Einströmens von Luft in das Wärmetransferrohr (304), sowie des Einstellens einer Strömungsmenge (Qp) von in die Luft einzumischenden Schleifpartikeln basierend auf einem Druckverlust zwischen einer Einlassseite (304a) und einer Auslassseite (304b) des Wärmetransferrohres (304),
einen Schritt des Berechnens einer bis zum Erreichen einer zulässigen Schleifdicke eines gekrümmten Abschnitts (A) des Wärmetransferrohres (304) benötigten zulässigen Schleifzeit (tA), basierend auf der Strömungsmenge (Qp) der Schleifpartikel, sowie des Berechnens einer bis zum Erreichen einer die Dekontamination des gesamten Wärmetransferrohres (304) bewirkenden Schleifmenge (W) benötigten Dekontaminationsschleifzeit (2t), und
einen Schritt des Einströmens von Luft im Gemisch mit den Schleifpartikeln in das Wärmetransferrohr (304) sowie des Einströmens der die Schleifpartikel enthaltenden Luft in Rückwärtsrichtung in das Wärmetransferrohr (304) innerhalb der Dekontaminationsschleifzeit (2t), sofern die zulässige Schleifzeit (tA) länger als die Dekontaminationsschleifzeit (2t) ist, und des Einströmens der die Schleifpartikel enthaltenden Luft in das Wärmetransferrohr (304) und des Einströmens der die Schleifpartikel enthaltenden Luft in das Wärmetransferrohr (304) in Rückwärtsrichtung innerhalb der zulässigen Schleifzeit (tA), sofern die zulässige Schleifzeit (tA) kürzer als die Dekontaminationsschleifzeit (2t) ist.

4. Dekontaminationsverfahren für einen Wärmetauscher nach Anspruch 3, wobei bei dem Schritt des Einströmens von Luft im Gemisch mit den Schleifpartikeln in das Wärmetransferrohr (304), sofern die zulässige Schleifzeit (tA) länger als die Dekontaminationsschleifzeit (2t) ist, die die Schleifpartikel enthaltende Luft für eine Zeit in das Wärmetransferrohr (304) einströmen gelassen wird, die der Hälfte der Dekontaminationsschleifzeit (2t) entspricht, und die die Schleifpartikel enthaltende Luft anschließend in Rückwärtsrichtung für eine Zeit in das Wärmetransferrohr (304) einströmen gelassen wird, die der Hälfte der Dekontaminationsschleifzeit (2t) entspricht, und, sofern die zulässige Schleifzeit (tA) kürzer als die Dekontaminationsschleifzeit (2t) ist, die die Schleifpartikel enthaltende Luft für eine Zeit in das Wärmetransferrohr (304) einströmen gelassen wird, die der Hälfte der zulässigen Schleifzeit (tA) entspricht, und die die Schleifpartikel enthaltende Luft anschließend in Rückwärtsrichtung für eine Zeit in das Wärmetransferrohr (304) einströmen gelassen wird, die der Hälfte der zulässigen Schleifzeit (tA) entspricht.

5. Dekontaminationsvorrichtung für einen Wärmetauscher zum Dekontaminieren des Inneren eines Wärmetransferrohres (304) in einem Wärmetauscher (3;11;12), wobei die Dekontaminationsvorrichtung umfasst:

einen Vorwärtseinströmungskreislauf (101), der bewirkt, dass Luft ausgehend von einem ersten Anschluss (304a) des Wärmetransferrohres (304) einen zweiten Anschluss (304b) erreicht und in das Wärmetransferrohr (304) einströmt,
einen Rückwärtseinströmungskreislauf (102), der bewirkt, dass Luft ausgehend von dem zweiten Anschluss (304b) des Wärmetransferrohres (304) den ersten Anschluss (304a) erreicht und in das Wärmetransferrohr (304) einströmt,
eine Schalteinheit (109), die selektiv zwischen dem Vorwärtseinströmungskreislauf (101) und dem Rückwärtseinströmungskreislauf (102) umschaltet,
eine Schleifmittelzuführeinheit (108), die eine Menge an Schleifpartikeln abmisst und die Schleifpartikel in Luft, welche in das Wärmetransferrohr (304) einströmt, einmischt; und
eine Steuereinheit (105), die die Schalteinheit (109) und die Schleifmittelzuführeinheit (109) steuert, wobei
die Steuereinheit (105) die Schalteinheit (109) dazu veranlasst, zwischen dem Vorwärtseinströmungskreislauf (101) und dem Rückwärtseinströmungskreislauf (102) umzuschalten, Luft in das Wärmetransferrohr (304) einströmen lässt, basierend auf einem Druckverlust zwischen einer Einlassseite (304a) und einer Auslassseite (304b) des Wärmetransferrohres (304) eine Strömungsmenge (Qp) an in die Luft einzumischenden Schleifpartikeln einstellt, basierend auf der Strömungsmenge (Qp) der Schleifpartikel eine bis zum Erreichen einer zulässigen Schleifdicke eines gekrümmten Abschnitts (A) des Wärmetransferrohres (304) benötigte zulässige Schleifzeit (tA) berechnet, die Schleifpartikel mittels der Schleifmittelzuführeinheit (109) in die Luft einmischt, und die Schalteinheit (109) dazu veranlasst, zwischen dem Vorwärtseinströmungskreislauf (101) und dem Rückwärtseinströmungskreislauf (102) innerhalb der zulässigen Schleifzeit (tA) umzuschalten.

6. Dekontaminationsvorrichtung für einen Wärmetauscher nach Anspruch 5, wobei die Steuereinheit (105) die zulässige Schleifzeit (tA) berechnet und die Schalteinheit (109) den Kreislauf auf den Rückwärtseinströmungskreislauf (102) schaltet, wenn, nachdem die Schalteinheit (109) den Kreislauf auf den Vorwärtseinströmungskreislauf (101) geschaltet hat währenddessen die Schleifpartikel mittels der Schleifmittelzuführeinheit (109) in die Luft eingemischt werden, eine der Hälfte der zulässigen Schleifzeit (tA) entsprechende Zeit verstrichen ist.

7. Dekontaminationsvorrichtung für einen Wärmetauscher zum Dekontaminieren des Inneren eines Wärmetransferrohres (304) in einem Wärmetauscher (3;11;12), wobei die Dekontaminationsvorrichtung umfasst:

einen Vorwärtseinströmungskreislauf (101), der bewirkt, dass Luft ausgehend von einem ersten Anschluss (304a) des Wärmetransferrohres (304) einen zweiten Anschluss (304b) erreicht und in das Wärmetransferrohr (304) einströmt,
einen Rückwärtseinströmungskreislauf (102), der veranlasst, dass Luft ausgehend von dem zweiten Anschluss (304b) des Wärmetransferrohres (304) den ersten Anschluss (304a) erreicht und in das Wärmetransferrohr (304) einströmt,
eine Schalteinheit (109), die selektiv zwischen dem Vorwärtseinströmungskreislauf (101) und dem Rückwärtseinströmungskreislauf (102) umschaltet,
eine Schleifmittelzuführeinheit (109), die eine Menge an Schleifpartikeln abmisst und die Schleifpartikel in Luft, welche in das Wärmetransferrohr (304) einströmt, einmischt, und
eine Steuereinheit (105), die die Schalteinheit (109) und die Schleifmittelzuführeinheit (109) steuert, wobei
die Steuereinheit (105) die Schalteinheit (109) dazu veranlasst, zwischen dem Vorwärtseinströmungskreislauf (101) und dem Rückwärtseinströmungskreislauf (102) umzuschalten, Luft in das Wärmetransferrohr (304) einströmen lässt, basierend auf einem Druckverlust zwischen einer Einlassseite (304a) und einer Auslassseite (304b) des Wärmetransferrohres (304) eine Strömungsmenge (Qp) an in die Luft einzumischenden Schleifpartikeln einstellt, basierend auf der Strömungsmenge (Qp) der Schleifpartikel eine bis zum Erreichen einer zulässigen Schleifdicke eines gekrümmten Abschnitts (A) des Wärmetransferrohres (304) benötigte zulässige Schleifzeit (tA) berechnet, eine bis zum Erreichen einer die Dekontamination des gesamten Wärmetransferrohres (304) bewirkenden Schleifmenge (W) benötigte Dekontaminationsschleifzeit (2t) berechnet, wobei die Schalteinheit (109), sofern die zulässige Schleifzeit (tA) länger als die Dekontaminationsschleifzeit (2t) ist, innerhalb der Dekontaminationsschleifzeit (2t) zwischen dem Vorwärtseinströmungskreislauf (101) und dem Rückwärtseinströmungskreislauf (102) umschaltet währenddessen die Schleifpartikel mittels der Schleifmittelzuführeinheit (109) in die Luft eingemischt werden, und die Schalteinheit (109), sofern die zulässige Schleifzeit (tA) kürzer als die Dekontaminationsschleifzeit (2t) ist, innerhalb der zulässigen Schleifzeit (tA) zwischen dem Vorwärtseinströmungskreislauf (101) und dem Rückwärtseinströmungskreislauf (102) umschaltet währenddessen die Schleifpartikel mittels der Schleifmittelzuführeinheit (109) in die Luft eingemischt werden.

8. Dekontaminationsvorrichtung für einen Wärmetauscher nach Anspruch 7, wobei die Steuereinheit (105) die zulässige Schleifzeit (tA) und die Dekontaminationsschleifzeit (2t) berechnet, die Schalteinheit (109) den Kreislauf auf den Rückwärtseinströmungskreislauf (102) schaltet, wenn die zulässige Schleifzeit (tA) länger als die Dekontaminationsschleifzeit (2t) ist und wenn, nachdem die Schalteinheit (109) den Kreislauf auf den Vorwärtseinströmungskreislauf (101) geschaltet hat währenddessen die Schleifpartikel mittels der Schleifmittelzuführeinheit (109) in die Luft eingemischt werden, eine der Hälfte der Dekontaminationsschleifzeit (2t) entsprechende Zeit verstrichen ist, und die Schalteinheit (109) den Kreislauf auf den Rückwärtseinströmungskreislauf (102) schaltet, wenn die zulässige Schleifzeit (tA) kürzer als die Dekontaminationsschleifzeit (2t) ist und wenn, nachdem die Schalteinheit (109) den Kreislauf auf den Vorwärtseinströmungskreislauf (101) geschaltet hat währenddessen die Schleifpartikel mittels der Schleifmittelzuführeinheit (109) in die Luft eingemischt werden, eine der Hälfte der zulässigen Schleifzeit (tA) entsprechende Zeit verstrichen ist.

Revendications

1. Procédé de décontamination d'un échangeur de chaleur pour décontaminer l'intérieur d'un tube de transfert de chaleur (304) dans un échangeur de chaleur (3 ; 11 ; 12), le procédé comprenant :

une étape de circulation d'air dans le tube de transfert de chaleur (304), et de réglage du débit (Qp) de particules abrasives à mélanger dans l'air sur la base d'une perte de pression entre un côté d'entrée (304a) et un côté de sortie (304b) du tube de transfert de chaleur (304) ;

une étape de calcul d'un temps de meulage autorisé (tA) nécessaire jusqu'à ce qu'une partie incurvée (A) du tube de transfert de chaleur (304) atteigne une épaisseur de meulage autorisée sur la base du débit (Qp) des particules abrasives ; et

une étape de circulation d'air mélangé avec les particules abrasives dans le tube de transfert de chaleur (304) dans les limites du temps de meulage autorisé (tA), et la circulation en sens inverse d'air mélangé avec les particules abrasives dans le tube de transfert de chaleur (304).

2. Procédé de décontamination d'un échangeur de chaleur selon la revendication 1, dans lequel, à l'étape de circulation d'air mélangé avec les particules abrasives dans le tube de transfert de chaleur (304), l'air avec les particules abrasives est amené à circuler dans le tube de transfert de chaleur (304) pendant un temps qui est égal à la moitié du temps de meulage autorisé (tA) et ensuite l'air avec les particules abrasives est amené à circuler en sens inverse dans le tube de transfert de chaleur (304) pendant un temps qui est égal à la moitié du temps de meulage autorisé (tA).

3. Procédé de décontamination d'un échangeur de chaleur pour décontaminer l'intérieur d'un tube de transfert de chaleur (304) dans un échangeur de chaleur (3 ; 11 ; 12), le procédé comprenant :

une étape de circulation d'air dans le tube de transfert de chaleur (304), et de réglage d'un débit (Qp) de particules abrasives à mélanger dans l'air sur la base d'une perte de pression entre un côté d'entrée (304a) et un côté de sortie (304b) du tube de transfert de chaleur (304) ;

une étape de calcul d'un temps de meulage autorisé (tA) nécessaire jusqu'à ce qu'une partie incurvée (A) du tube de transfert de chaleur (304) atteigne une épaisseur de meulage autorisée sur la base du débit (Qp) des particules abrasives, et de calcul d'un temps de meulage de décontamination (2t) nécessaire jusqu'à ce que le tube de transfert de chaleur (304) entier atteigne une quantité de meulage d'accomplissement de décontamination (W) ; et

une étape de circulation d'air mélangé avec les particules abrasives dans le tube de transfert de chaleur (304) et de circulation en sens inverse de l'air avec les particules abrasives dans le tube de transfert de chaleur (304) dans les limites du temps de meulage de décontamination (2t) lorsque le temps de meulage autorisé (tA) est plus long que le temps de meulage de décontamination (2t), et de circulation de l'air avec les particules abrasives dans le tube de transfert de chaleur (304) et de circulation en sens inverse de l'air avec les particules abrasives dans le tube de transfert de chaleur (304) dans les limites du temps de meulage autorisé (tA) lorsque le temps de meulage autorisé (tA) est plus court que le temps de meulage de décontamination (2t).

4. Procédé de décontamination d'un échangeur de chaleur selon la revendication 3, dans lequel, à l'étape de circulation d'air mélangé avec les particules abrasives dans le tube de transfert de chaleur (304), l'air avec les particules abrasives est amené à circuler dans le tube de transfert de chaleur (304) pendant un temps qui est égal à une moitié du temps de meulage de décontamination (2t) et ensuite l'air avec les particules abrasives est amené à circuler en sens inverse dans le tube de transfert de chaleur (304) pendant un temps qui est égal à une moitié du temps de meulage de décontamination (2t) lorsque le temps de meulage autorisé (tA) est plus long que le temps de meulage de décontamination (2t), et l'air avec les particules abrasives est amené à circuler dans le tube de transfert de chaleur (304) pendant un temps qui est égal à une moitié du temps de meulage autorisé (tA) et ensuite l'air avec les particules abrasives est amené à circuler en sens inverse dans le tube de transfert de chaleur (304) pendant un temps qui est égal à une moitié du temps de meulage autorisé (tA) lorsque le temps de meulage autorisé (tA) est plus court que le temps de meulage de décontamination (2t).

5. Appareil de décontamination d'un échangeur de chaleur pour décontaminer l'intérieur d'un tube de transfert de chaleur (304) dans un échangeur de chaleur (3 ; 11 ; 12), l'appareil de décontamination comprenant :

un circuit d'entrée en avant (101) qui amène de l'air à atteindre un deuxième orifice (304b) à partir d'un premier orifice (304a) du tube de transfert de chaleur (304) et à circuler dans le tube de transfert de chaleur (304) ;

un circuit d'entrée en arrière (102) qui amène de l'air à atteindre le premier orifice (304a) à partir du deuxième orifice (304b) du tube de transfert de chaleur (304) et à circuler dans le tube de transfert de chaleur (304) ;

une unité de commutation (109) qui commute de manière sélective entre le circuit d'entrée en avant (101) et le circuit d'entrée en arrière (102) ;

une unité de fourniture d'abrasif (108) qui mesure une quantité de particules abrasives et qui mélange les particules abrasives dans l'air qui circule dans le tube de transfert de chaleur (304) ; et

une unité de commande (105) qui commande l'unité de commutation (109) et l'unité de fourniture d'abrasif (109), dans lequel l'unité de commande (105) amène l'unité de commutation (109) à commuter entre le circuit d'entrée en avant (101) et le circuit d'entrée en arrière (102), fait circuler de l'air dans le tube de transfert de chaleur (304), règle un débit (Qp) de particules abrasives à mélanger dans l'air sur la base d'une perte de pression entre un côté d'entrée (304a) et un côté de sortie (304b) du tube de transfert de chaleur (304), calcule un temps de meulage autorisé (tA) nécessaire jusqu'à ce qu'une partie incurvée (A) du tube de transfert de chaleur (304) atteigne une épaisseur de meulage autorisée sur la base du débit (Qp) des particules abrasives, mélange les particules abrasives dans l'air par l'unité de fourniture d'abrasif (109), et amène l'unité de commutation (109) à commuter entre le circuit d'entrée en avant (101) et le circuit d'entrée en arrière (102) dans les limites du temps de meulage autorisé (tA).

6. Appareil de décontamination d'un échangeur de chaleur selon la revendication 5, dans lequel l'unité de commande (105) calcule le temps de meulage autorisé (tA), et, lorsqu'un temps qui est égal à une moitié du temps de meulage autorisé (tA) s'est écoulé après que l'unité de commutation (109) a commuté le circuit vers le circuit d'entrée en avant (101) tout en mélangeant les particules abrasives dans l'air par l'unité de fourniture d'abrasif (109), l'unité de commutation (109) commute le circuit vers le circuit d'entrée en arrière (102).

7. Appareil de décontamination d'un échangeur de chaleur pour décontaminer l'intérieur d'un tube de transfert de chaleur (304) dans un échangeur de chaleur (3 ; 11 ; 12), l'appareil de décontamination comprenant :

un circuit d'entrée en avant (101) qui amène de l'air à atteindre un deuxième orifice (304b) à partir d'un premier orifice (304a) du tube de transfert de chaleur (304) et à circuler dans le tube de transfert de chaleur (304) ;
un circuit d'entrée en arrière (102) qui amène de l'air à atteindre le premier orifice (304a) à partir du deuxième orifice (304b) du tube de transfert de chaleur (304) et à circuler dans le tube de transfert de chaleur (304) ;
une unité de commutation (109) qui commute de manière sélective entre le circuit d'entrée en avant (101) et le circuit d'entrée en arrière (102) ;
une unité de fourniture d'abrasif (109) qui mesure une quantité de particules abrasives et mélange les particules abrasives dans l'air qui circule dans le tube de transfert de chaleur (304) ; et
une unité de commande (105) qui commande l'unité de commutation (109) et l'unité de fourniture d'abrasif (109), dans lequel
l'unité de commande (105) amène l'unité de commutation (109) à commuter entre le circuit d'entrée en avant (101) et le circuit d'entrée en arrière (102), fait circuler de l'air dans le tube de transfert de chaleur (304), règle un débit (Qp) de particules abrasives à mélanger dans l'air sur la base d'une perte de pression entre un côté d'entrée (304a) et un côté de sortie (304b) du tube de transfert de chaleur (304), calcule un temps de meulage autorisé (tA) nécessaire jusqu'à ce qu'une partie incurvée (A) du tube de transfert de chaleur (304) atteigne une épaisseur de meulage autorisée sur la base du débit (Qp) des particules abrasives, calcule un temps de meulage de décontamination (2t) qui est nécessaire jusqu'à ce que le tube de transfert de chaleur (304) entier atteigne la quantité de meulage d'accomplissement de décontamination (W), l'unité de commutation (109) commute entre le circuit d'entrée en avant (101) et le circuit d'entrée en arrière (102) dans les limites du temps de meulage de décontamination (2t) tout en mélangeant les particules abrasives dans l'air par l'unité de fourniture d'abrasif (109) lorsque le temps de meulage autorisé (tA) est plus long que le temps de meulage de décontamination (2t), et l'unité de commutation (109) commute entre le circuit d'entrée en avant (101) et le circuit d'entrée en arrière (102) dans les limites du temps de meulage autorisé (tA) tout en mélangeant les particules abrasives dans l'air par l'unité de fourniture d'abrasif (109) lorsque le temps de meulage autorisé (tA) est plus court que le temps de meulage de décontamination (2t).

8. Appareil de décontamination d'un échangeur de chaleur selon la revendication 7, dans lequel l'unité de commande (105) calcule le temps de meulage autorisé (tA) et le temps de meulage de décontamination (2t), l'unité de commutation (109) commute le circuit vers le circuit d'entrée en arrière (102) lorsque le temps de meulage autorisé (tA) est plus long que le temps de meulage de décontamination (2t) et lorsqu'un temps qui est égal à une moitié du temps de meulage de décontamination (2t) s'est écoulé après que l'unité de commutation (109) a commuté le circuit vers le circuit d'entrée en avant (101) tout en mélangeant les particules abrasives dans l'air par l'unité de fourniture d'abrasif (109), et l'unité de commutation (109) commute le circuit vers le circuit d'entrée en arrière (102) lorsque le temps de meulage autorisé (tA) est plus court que le temps de meulage de décontamination (2t) et lorsqu'un temps qui est égal à une moitié du temps de meulage autorisé (tA) s'est écoulé après que l'unité de commutation (109) a commuté le circuit vers le circuit d'entrée en avant (101) tout en mélangeant les particules abrasives dans l'air par l'unité de fourniture d'abrasif (109).

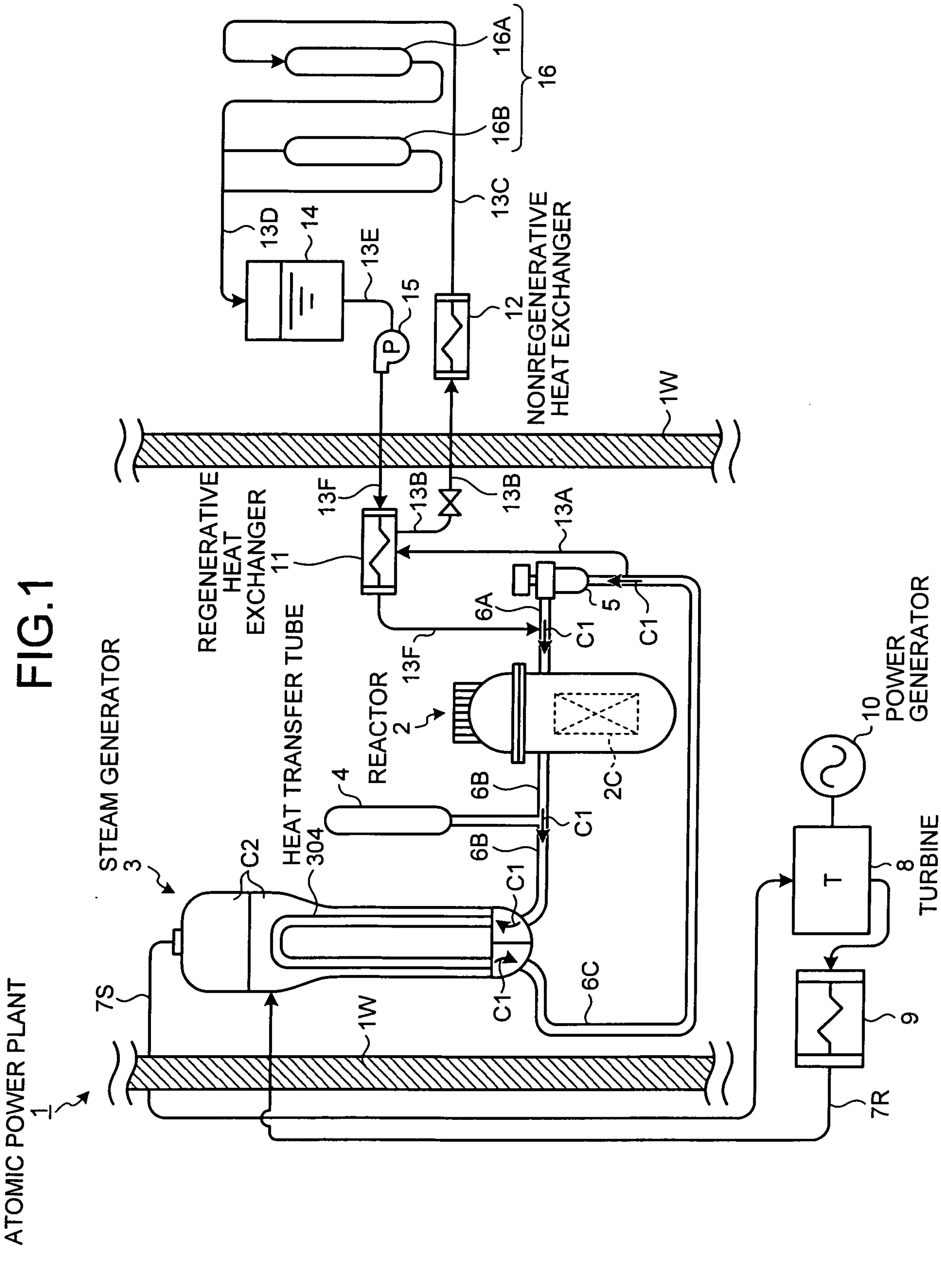

ATOMIC POWER PLANT
1
STEAM GENERATOR
3
HEAT TRANSFER TUBE
304
REACTOR
2
REGENERATIVE HEAT EXCHANGER
11
NONREGENERATIVE HEAT EXCHANGER
12
POWER GENERATOR
10
TURBINE
8
T
P
1W
7S
7R
9
C1
C2
4
5
6A
6B
6C
2C
13A
13B
13C
13D
13E
13F
14
15
16
16A
16B

FIG.1

FIG.2

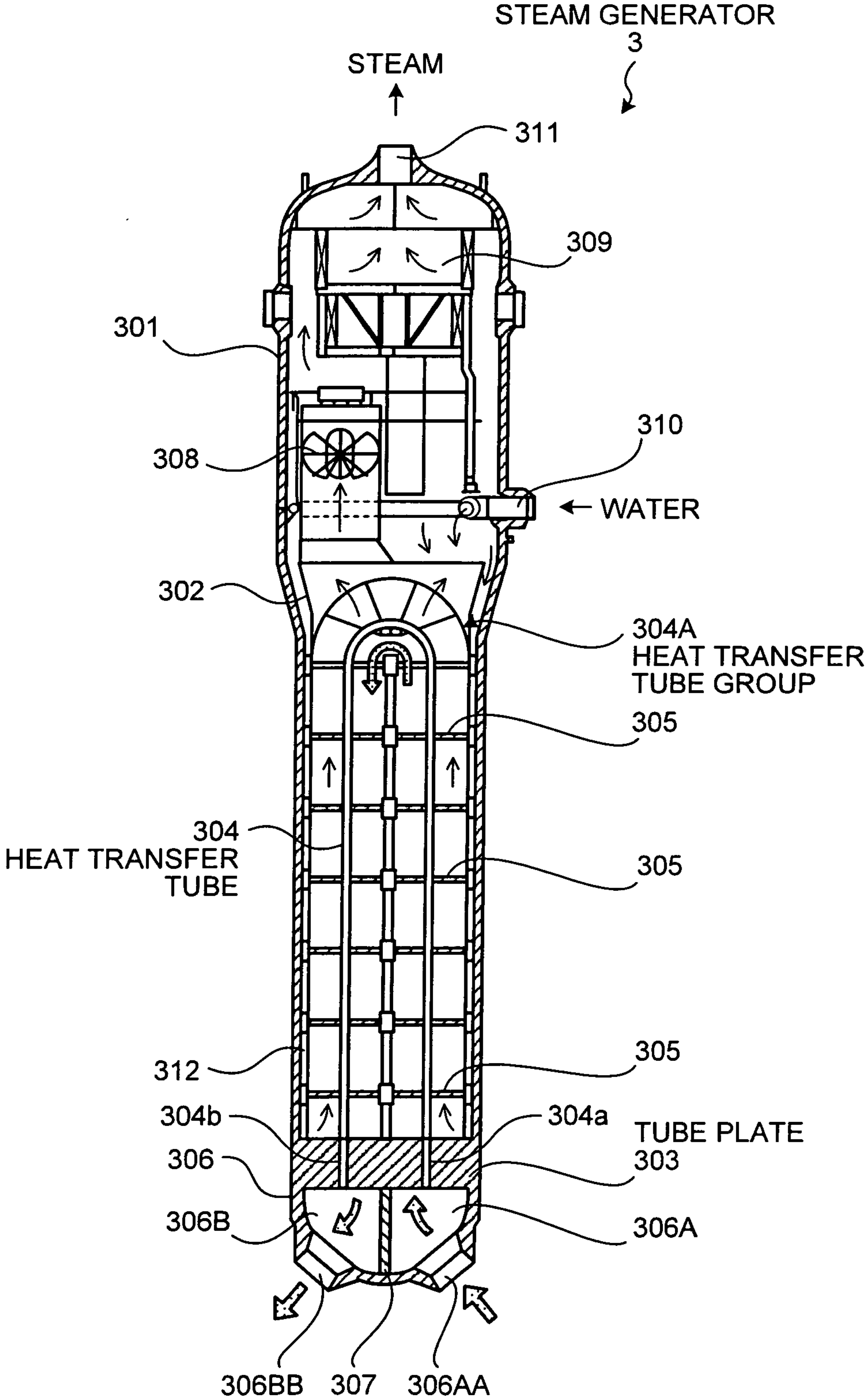

STEAM GENERATOR
3
STEAM
311
309
301
310
WATER
308
302
304A
HEAT TRANSFER
TUBE GROUP
305
304
HEAT TRANSFER
TUBE
305
312
305
304b
304a
TUBE PLATE
303
306
306B
306A
306BB
307
306AA

FIG.3

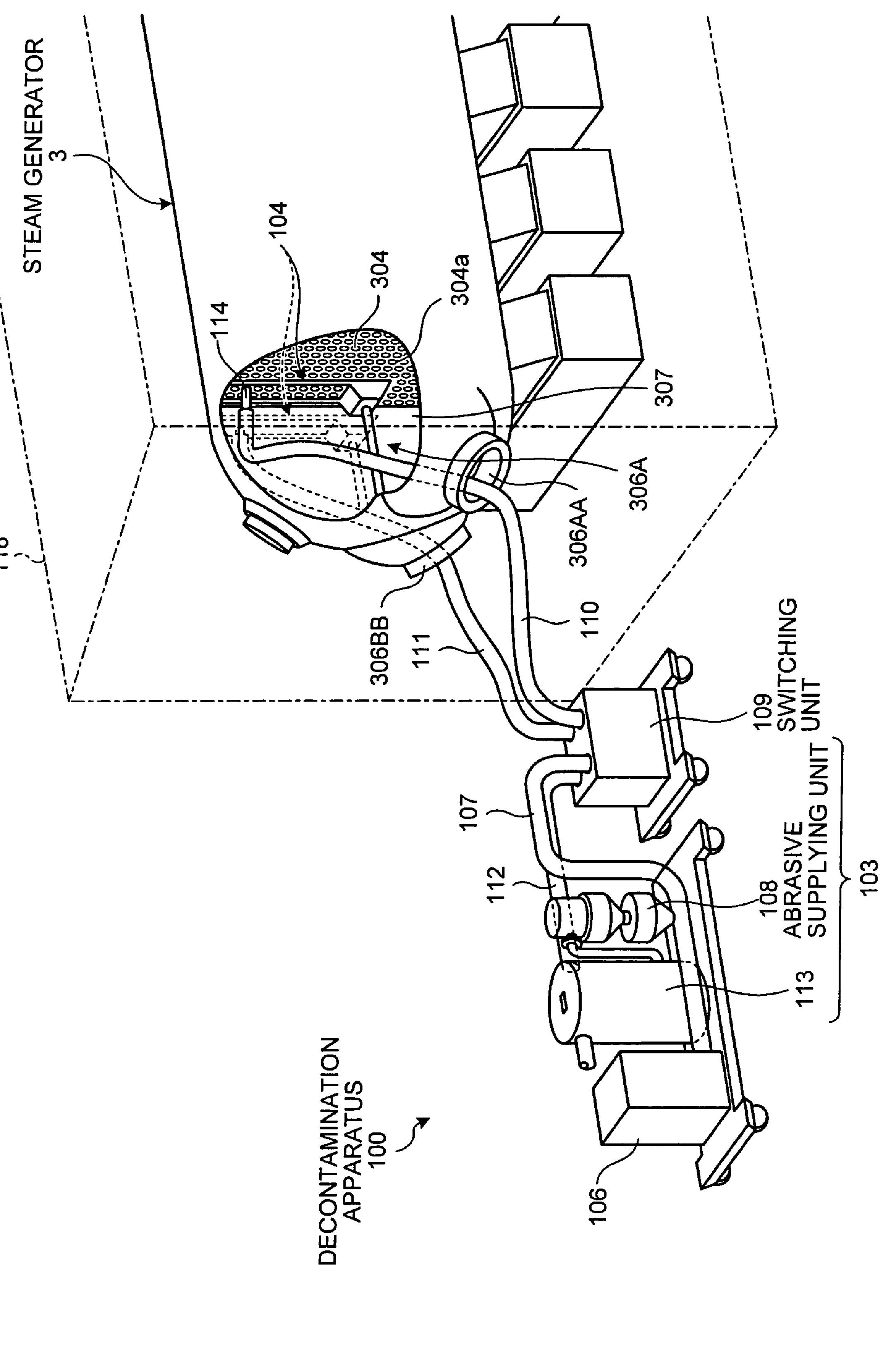

STEAM GENERATOR
3
118
104
114
304
304a
307
306A
306AA
306BB
111
110
109
SWITCHING UNIT
107
112
108
ABRASIVE SUPPLYING UNIT
103
113
106
DECONTAMINATION APPARATUS
100

FIG.4

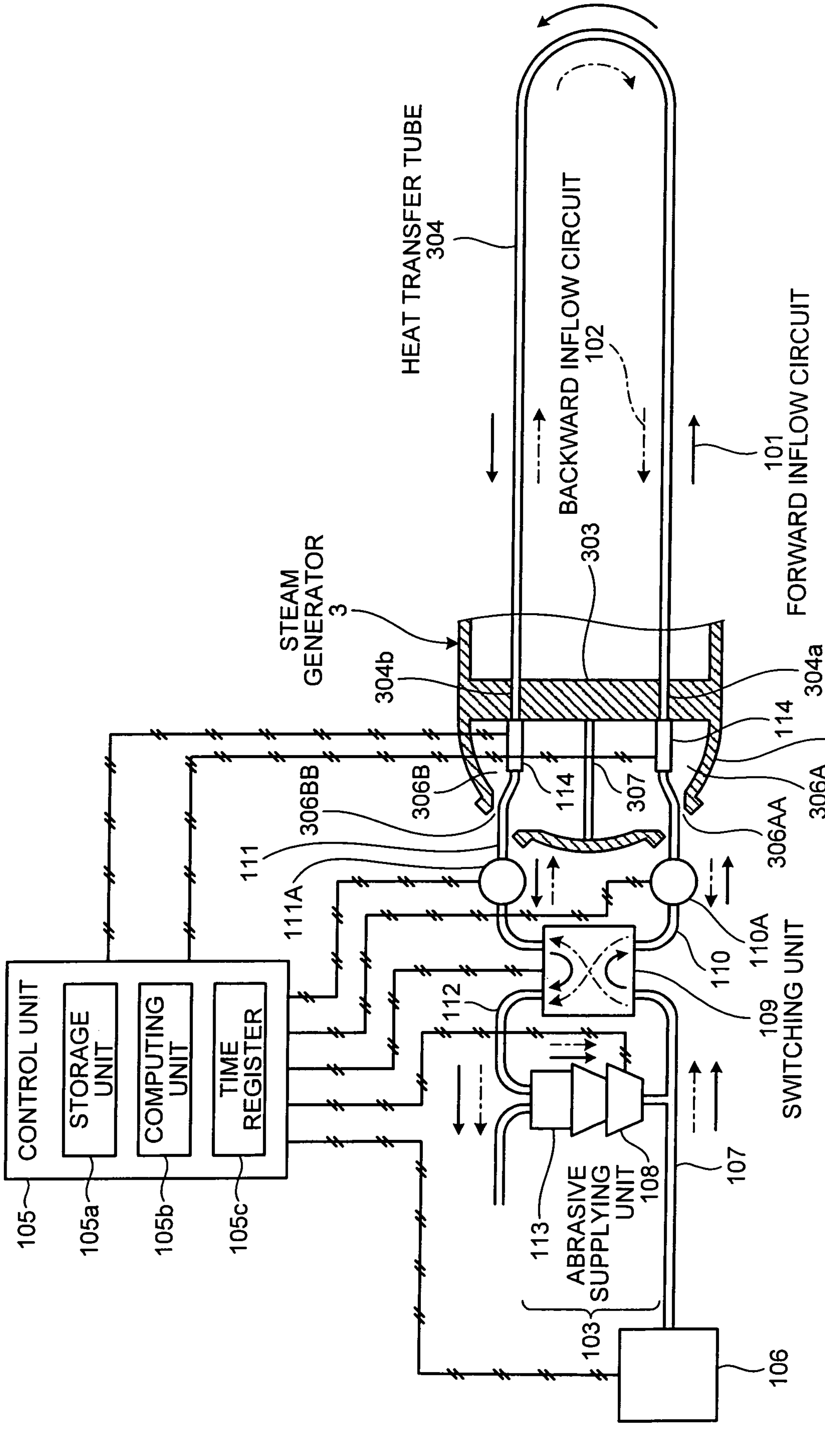

HEAT TRANSFER TUBE
304
BACKWARD INFLOW CIRCUIT
102
FORWARD INFLOW CIRCUIT
101
303
STEAM
GENERATOR
3
304b
304a
114
306
306A
306AA
306B
306BB
307
111
111A
110
110A
109
SWITCHING UNIT
112
CONTROL UNIT
STORAGE
UNIT
COMPUTING
UNIT
TIME
REGISTER
105
105a
105b
105c
113
ABRASIVE
SUPPLYING
UNIT
108
107
103
106

FIG.5

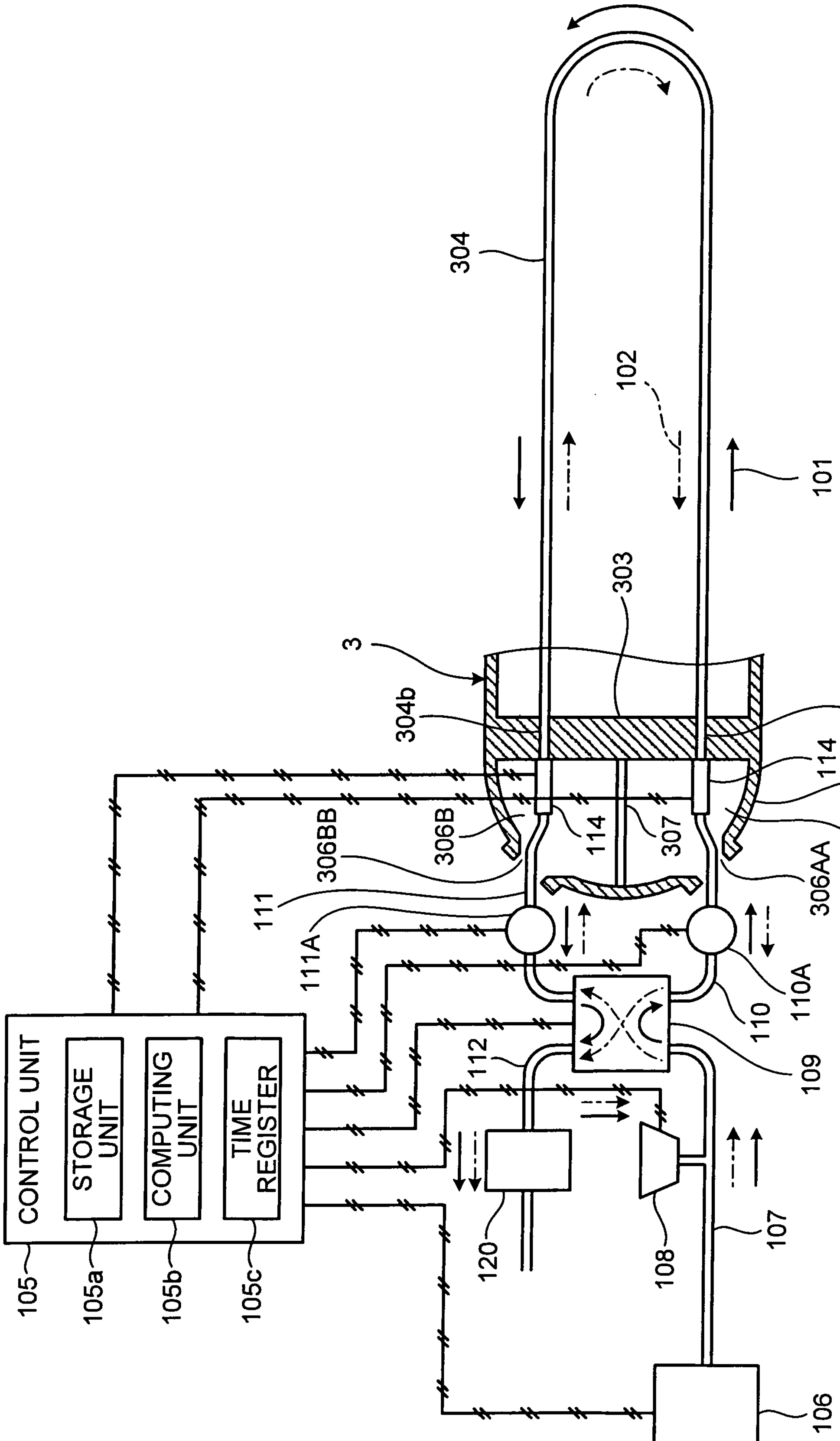

CONTROL UNIT
STORAGE UNIT
COMPUTING UNIT
TIME REGISTER
105
105a
105b
105c
106
107
108
109
110
110A
111
111A
112
114
120
3
101
102
303
304
304a
304b
306
306A
306AA
306B
306BB
307

FIG.6

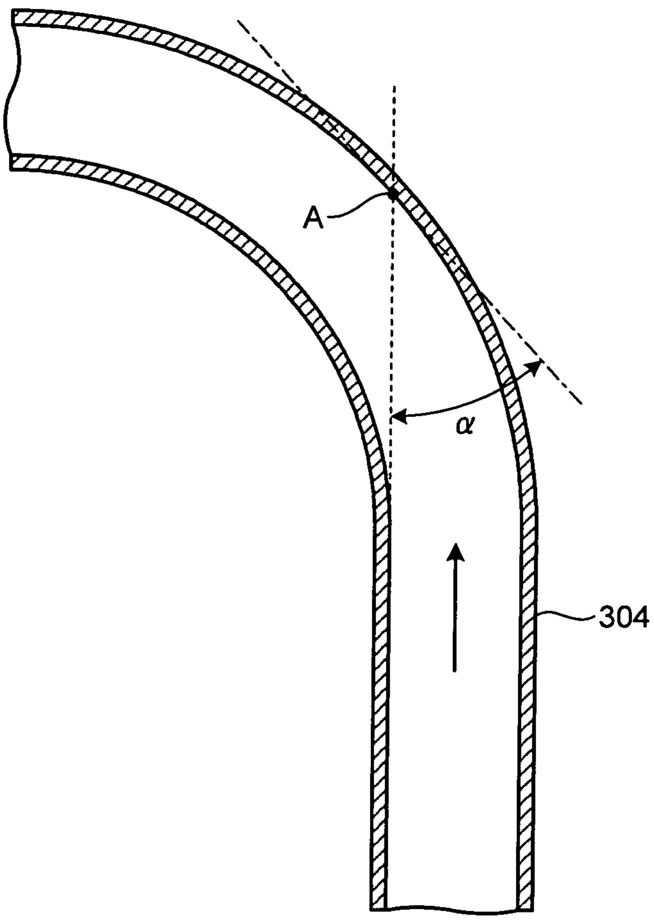


FIG.7

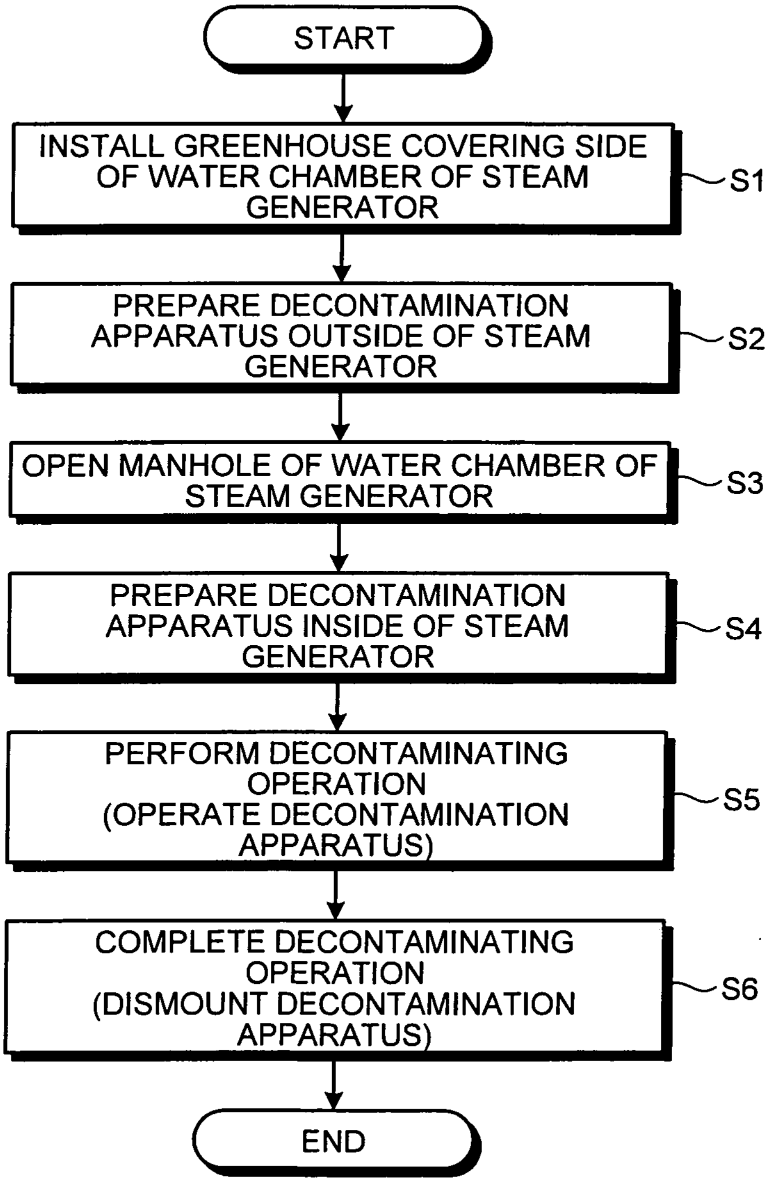

START
INSTALL GREENHOUSE COVERING SIDE OF WATER CHAMBER OF STEAM GENERATOR
S1
PREPARE DECONTAMINATION APPARATUS OUTSIDE OF STEAM GENERATOR
S2
OPEN MANHOLE OF WATER CHAMBER OF STEAM GENERATOR
S3
PREPARE DECONTAMINATION APPARATUS INSIDE OF STEAM GENERATOR
S4
PERFORM DECONTAMINATING OPERATION (OPERATE DECONTAMINATION APPARATUS)
S5
COMPLETE DECONTAMINATING OPERATION (DISMOUNT DECONTAMINATION APPARATUS)
S6
END

FIG.8

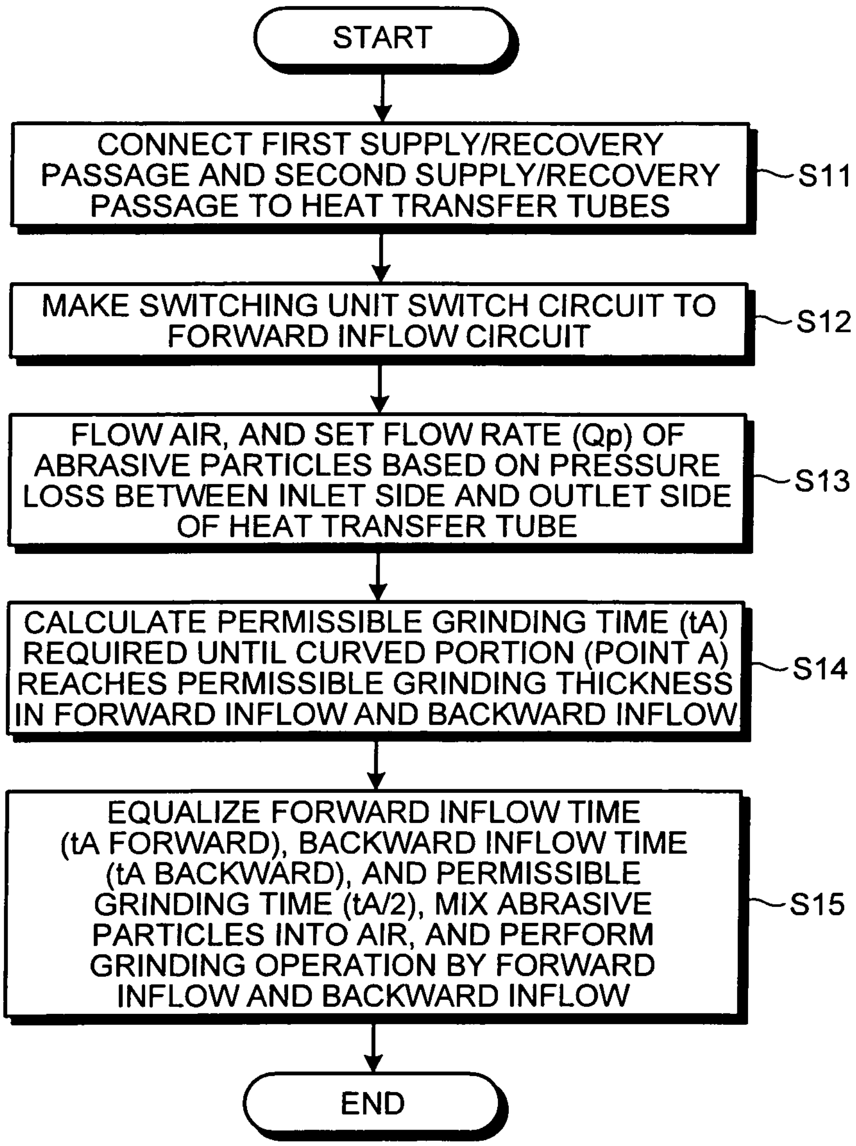

START
CONNECT FIRST SUPPLY/RECOVERY PASSAGE AND SECOND SUPPLY/RECOVERY PASSAGE TO HEAT TRANSFER TUBES
S11
MAKE SWITCHING UNIT SWITCH CIRCUIT TO FORWARD INFLOW CIRCUIT
S12
FLOW AIR, AND SET FLOW RATE (Qp) OF ABRASIVE PARTICLES BASED ON PRESSURE LOSS BETWEEN INLET SIDE AND OUTLET SIDE OF HEAT TRANSFER TUBE
S13
CALCULATE PERMISSIBLE GRINDING TIME (tA) REQUIRED UNTIL CURVED PORTION (POINT A) REACHES PERMISSIBLE GRINDING THICKNESS IN FORWARD INFLOW AND BACKWARD INFLOW
S14
EQUALIZE FORWARD INFLOW TIME (tA FORWARD), BACKWARD INFLOW TIME (tA BACKWARD), AND PERMISSIBLE GRINDING TIME (tA/2), MIX ABRASIVE PARTICLES INTO AIR, AND PERFORM GRINDING OPERATION BY FORWARD INFLOW AND BACKWARD INFLOW
S15
END

FIG.9A

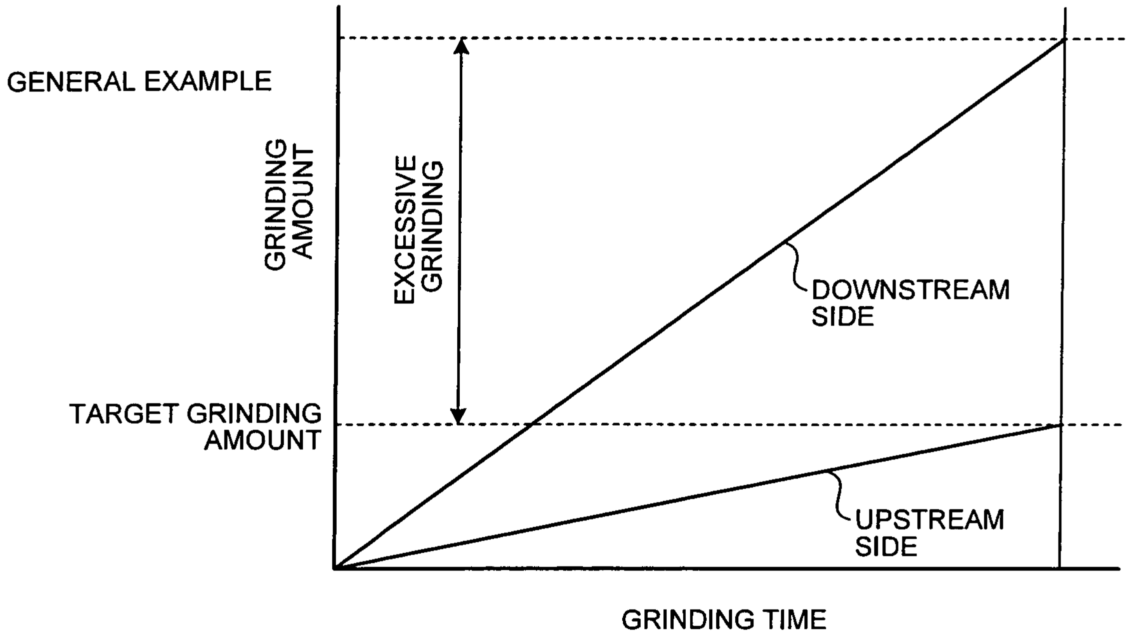

GENERAL EXAMPLE
GRINDING AMOUNT
EXCESSIVE GRINDING
DOWNSTREAM SIDE
TARGET GRINDING AMOUNT
UPSTREAM SIDE
GRINDING TIME

FIG.9B

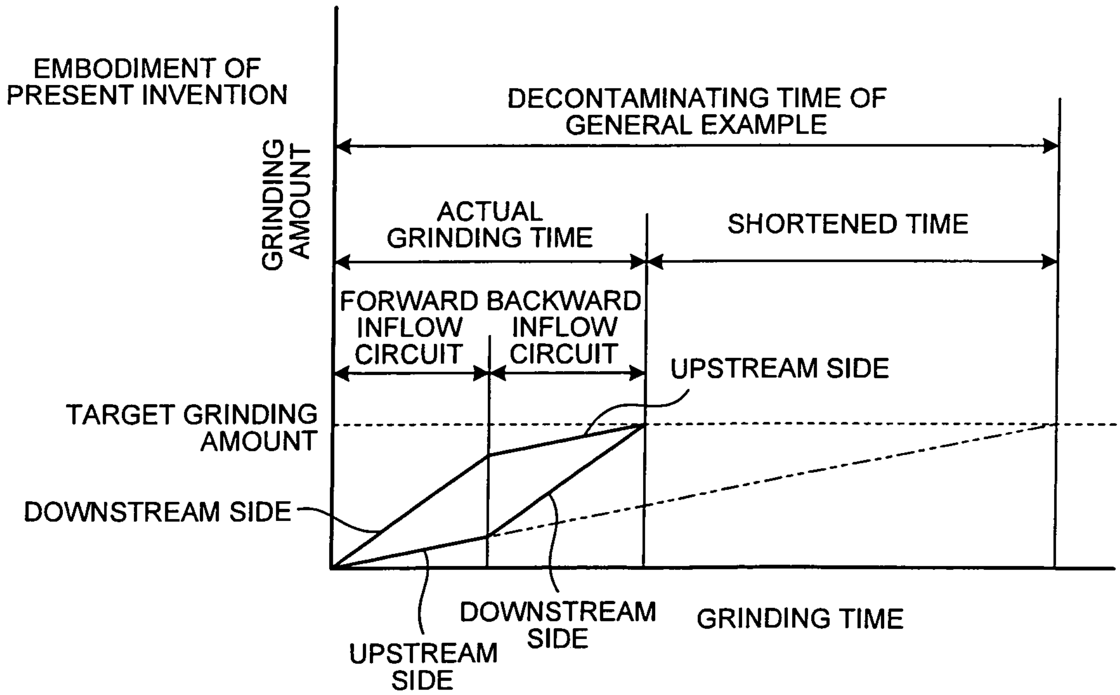

EMBODIMENT OF PRESENT INVENTION
GRINDING AMOUNT
DECONTAMINATING TIME OF GENERAL EXAMPLE
ACTUAL GRINDING TIME
SHORTENED TIME
FORWARD INFLOW CIRCUIT
BACKWARD INFLOW CIRCUIT
UPSTREAM SIDE
TARGET GRINDING AMOUNT
DOWNSTREAM SIDE
DOWNSTREAM SIDE
GRINDING TIME
UPSTREAM SIDE

FIG.10

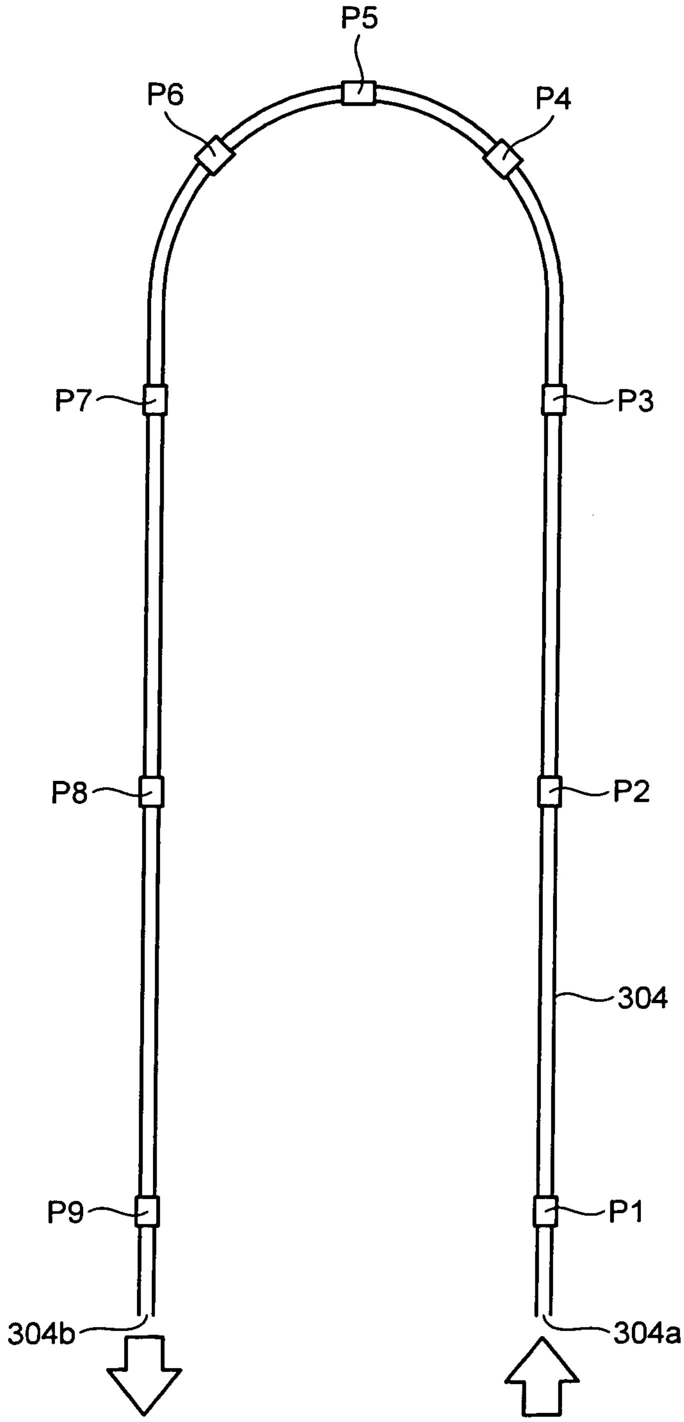
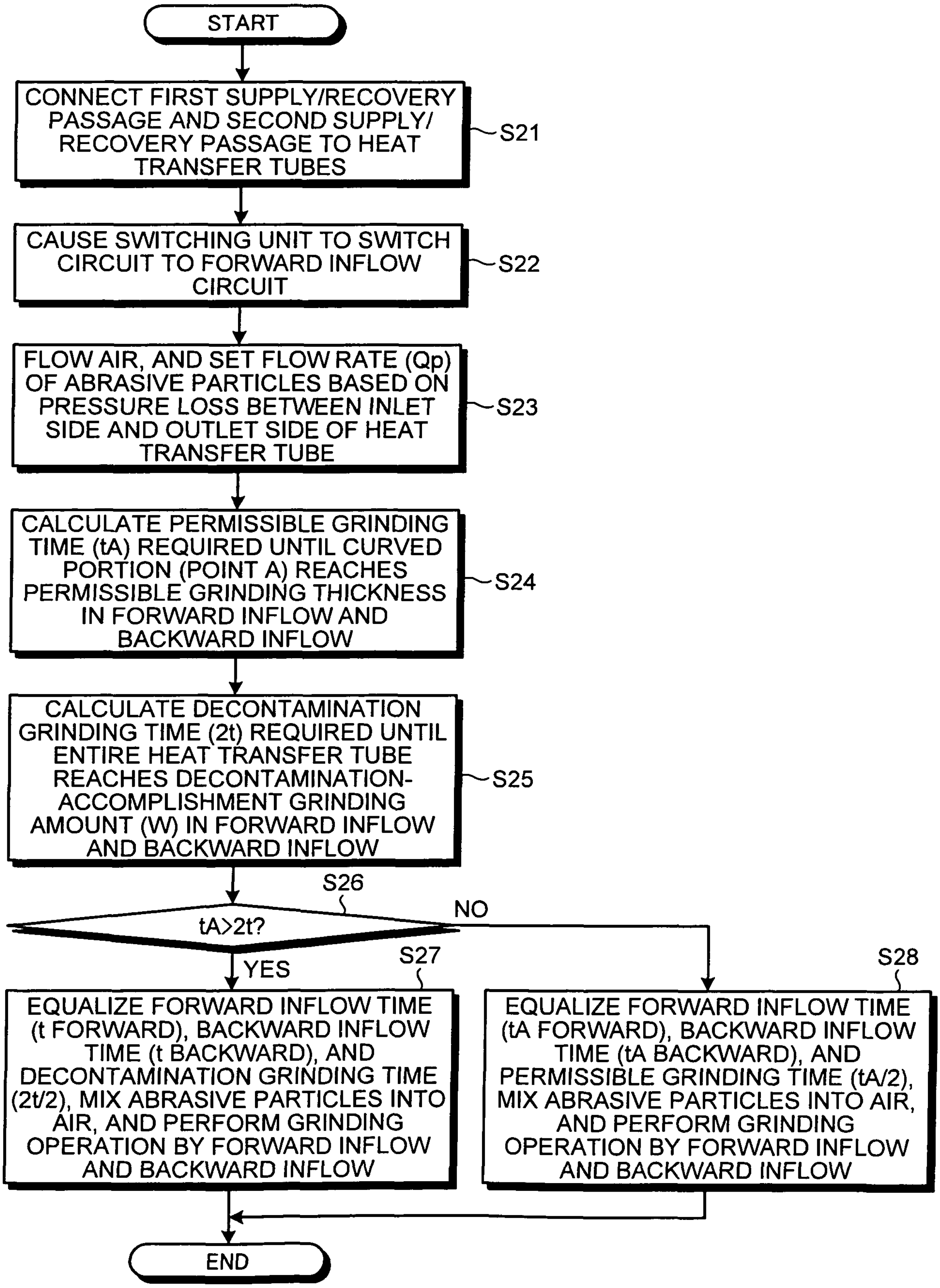


FIG.11


START
CONNECT FIRST SUPPLY/RECOVERY PASSAGE AND SECOND SUPPLY/ RECOVERY PASSAGE TO HEAT TRANSFER TUBES
S21
CAUSE SWITCHING UNIT TO SWITCH CIRCUIT TO FORWARD INFLOW CIRCUIT
S22
FLOW AIR, AND SET FLOW RATE (Qp) OF ABRASIVE PARTICLES BASED ON PRESSURE LOSS BETWEEN INLET SIDE AND OUTLET SIDE OF HEAT TRANSFER TUBE
S23
CALCULATE PERMISSIBLE GRINDING TIME (tA) REQUIRED UNTIL CURVED PORTION (POINT A) REACHES PERMISSIBLE GRINDING THICKNESS IN FORWARD INFLOW AND BACKWARD INFLOW
S24
CALCULATE DECONTAMINATION GRINDING TIME (2t) REQUIRED UNTIL ENTIRE HEAT TRANSFER TUBE REACHES DECONTAMINATION-ACCOMPLISHMENT GRINDING AMOUNT (W) IN FORWARD INFLOW AND BACKWARD INFLOW
S25
S26
tA>2t?
NO
YES
S27
EQUALIZE FORWARD INFLOW TIME (t FORWARD), BACKWARD INFLOW TIME (t BACKWARD), AND DECONTAMINATION GRINDING TIME (2t/2), MIX ABRASIVE PARTICLES INTO AIR, AND PERFORM GRINDING OPERATION BY FORWARD INFLOW AND BACKWARD INFLOW
S28
EQUALIZE FORWARD INFLOW TIME (tA FORWARD), BACKWARD INFLOW TIME (tA BACKWARD), AND PERMISSIBLE GRINDING TIME (tA/2), MIX ABRASIVE PARTICLES INTO AIR, AND PERFORM GRINDING OPERATION BY FORWARD INFLOW AND BACKWARD INFLOW
END

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP S60678895 B **[0004]**