

DESCRIPTION

Title of Invention

METHOD AND APPARATUS FOR CLEANING HEAT TRANSFER TUBE IN MARINE BOILER

Technical Field:

[0001] The present invention relates to a method and apparatus for cleaning heat transfer tubes in a marine boiler, and more particularly to a cleaning method and apparatus for removing scales from outer surfaces of evaporator tubes, superheater tubes, and screen tubes disposed in a boiler which is installed on a marine vessel.

Background Art:

[0002] Marine boilers have a number of heat transfer tubes disposed therein for circulating water or steam therethrough. The heat transfer tubes for use in marine boilers include evaporator tubes, superheater tubes, and screen tubes. When a combustion gas is brought into contact with a heat transfer tube, the heat transfer tube recovers heat from the combustion gas by way of a heat exchange between the combustion gas and the heat transfer tube. However, various components included in the combustion gas are clumped together as deposits called scales on the surface of the heat transfer tube.

[0003] Generally, heavy oil C is used as fuel oil for marine boilers. Since the heavy oil C contains a lot of sulfur content, when the heavy oil C is combusted, the sulfur content is chemically bound to oxygen, thus producing sulfurous acid which is deposited as combustion residues on heat transfer tubes and a refractory material at the bottom of the boiler. Therefore, the scales deposited on the heat transfer tubes contain sulfurous acid.

[0004] Conventionally, it has been customary for workers to enter marine boilers and clean them with water in order to remove the scales deposited on evaporator tubes, superheater tubes, and screen tubes.

When the evaporator tubes, the superheater tubes, the screen tubes, and the refractory material in the boilers, on which sulfurous acid is deposited, are cleaned with water, sulfuric acid is produced due to a chemical reaction represented by $\text{H}_2\text{O} + \text{SO}_3 \rightarrow \text{H}_2\text{SO}_4$ and becomes acid waste liquid. Sulfuric-acid-containing water which has become acid causes sulfuric acid corrosion, which is referred to as low-temperature corrosion, to the evaporator tubes, the superheater tubes, and the screen tubes.

[0005] The evaporator tubes, the superheater tubes, and the screen tubes which have undergone sulfuric acid corrosion have outer surfaces eroded, and hence have their wall thicknesses reduced. If the boiler is kept continuously in operation, then the tubes cannot be endured to break open under the internal pressure therein. When the tubes break open, the boiler needs to be shut down and the broken tubes have to be repaired. Thus, the marine vessel equipped with the boiler becomes out of service during the repair.

[0006] Further, when the boiler is to be cleaned with water, the refractory material is protected in advance against water infiltration. If the refractory material is not sufficiently protected, then the acid waste liquid infiltrates into the refractory material, and thus the refractory material deteriorates and fails to function properly. Then, a steel sheet called a skin casing which covers the outer surface of the boiler is liable to be pitted by sulfuric acid corrosion called low-temperature corrosion.

When the steel sheet called a skin casing which covers the outer surface of the boiler is pitted, the combustion gas leaks out of the boiler into the engine room, causing a highly dangerous situation fatal to human beings. Further, the water quality of wastewater that gathers on the bottom of the boiler after cleaning becomes acid by the sulfurous acid contained in the scales, and the treatment work of wastewater needs to be performed separately.

Citation List

Patent literature

[0007] Patent document 1: Japanese patent publication No. 60-36526

Summary of Invention

Technical Problem

[0008] As described above, the process of removing the scales by cleaning the evaporator tubes, the superheater tubes, and the screen tubes of the boiler with water suffers various problems in that because sulfuric-acid-containing water is produced, the evaporator tubes, the superheater tubes, and the screen tubes are subjected to sulfuric acid corrosion, the refractory material is deteriorated, and the acid waste liquid needs to be treated.

Therefore, the present inventors have intensively studied processes that are capable of removing scales from evaporator tubes, superheater tubes, and screen tubes disposed in marine boilers without using cleaning water.

[0009] Thus, the present inventors have studied the application of blast cleaning which ejects blasting materials to remove deposits with impacting forces of the blasting materials, to the cleaning of evaporator tubes, superheater tubes, and screen tubes disposed in marine boilers.

First, the present inventors have analyzed the state of the surfaces of evaporator tubes, superheater tubes, and screen tubes and have also analyzed scales deposited on the steel tubes. As a result, the present inventors have found that thin oxide films are formed on the surfaces of the base materials of evaporator tubes, superheater tubes, and screen tubes, and scales are deposited on the surfaces of the oxide films.

The scales have the following three main constituents:

- Vanadium oxide (V_2O_5): 40 to 50 %
- Hematite (Fe_2O_3): 20 to 25 %
- Sulfur oxide: about 10 %
- Others: oxides of Ni, Na, Si, Al, Cr, etc. each within several %.

[0010] Steel alloy tubes (STBA22, STBA24, KA-STBA28, STBA35, etc.) for use in boilers and heat exchangers are used for evaporator tubes, superheater tubes, and screen tubes in marine boilers. While the boiler is in operation, the surfaces of these steel tubes react with oxygen in the air, thus forming thin oxide films thereon. The oxide film comprises a dense-structural iron oxide film which is mainly composed of triiron tetraoxide (Fe_3O_4), and is highly wear-resistant and corrosion-resistant.

[0011] Therefore, the present inventors have found that it is preferable from the standpoint of protecting the base materials of the steel tubes to remove the scales from the evaporator tubes, the superheater tubes, and the screen tubes by blast cleaning, but to leave the highly wear-resistant and corrosion-resistant oxide films unremoved.

[0012] The present inventors then conducted a blast cleaning test on evaporator tubes, superheater tubes, and screen tubes for use in marine boilers, using a ceramic blasting material, glass beads which are used for blast cleaning of tubes or the like. After the blast cleaning test, the present inventors checked if scales were removed from the evaporator tubes, the superheater tubes, and the screen tubes or not, and analyzed the surfaces of the steel tubes. As a result, the present inventors discovered that not only the scales were removed from the evaporator tubes, the superheater tubes, and the screen tubes, but also the base materials of the steel tubes were ground off.

[0013] The present invention has been made in view of the above circumstances. It is therefore an object of the present invention to provide a method and apparatus for cleaning a heat transfer tube such as an evaporator tube, a superheater tube, a screen tube in a marine boiler which can remove scales therefrom by blast cleaning without adversely affecting an oxide film and a base material of the heat transfer tube.

Solution to Problem

[0014] When blast cleaning is to be performed on a heat transfer tube in a marine boiler using a ceramic blasting material, glass beads, the present inventors attempted to leave an oxide film on a surface of a heat transfer tube by ejecting the blasting material

under a low pressure to reduce an impact force applied to the heat transfer tube at the time of the blasting. However, the present inventors found that the base material of the heat transfer tube is exposed when the heat transfer tube is blast-cleaned at one location for about five seconds under a low pressure of about 0.2 MPa.

Therefore, the present inventors have repeatedly blast-cleaned heat transfer tubes using various blasting materials. As a result, the present inventors have discovered that it is possible to remove only scales from the heat transfer tubes without removing oxide films therefrom, by using a plant blasting material or a resin blasting material.

[0015] In order to achieve the above object, according to a first aspect of the present invention, there is provided a cleaning method of removing scales deposited on a heat transfer tube in a marine boiler by ejecting a blasting material to the heat transfer tube, comprising: removing scales deposited on the heat transfer tube by using a plant blasting material or a resin blasting material as a blasting material; and leaving unremoved an oxide film formed on a surface of the heat transfer tube.

According to the present invention, it is possible to remove only scales from the heat transfer tube without removing an oxide film therefrom, by performing blast cleaning using a plant blasting material or a resin blasting material. The oxide film formed on the heat transfer tube comprises a dense-structural iron oxide film which is mainly composed of triiron tetraoxide (Fe_3O_4), and is highly wear-resistant and corrosion-resistant. Therefore, the oxide film can protect the base material of the heat transfer tube.

According to the blast cleaning using a plant blasting material or a resin blasting material, it is possible to remove only scales from the heat transfer tube without removing an oxide film therefrom even if the blasting material is applied under a high pressure for a long period of time, e.g., under an ejection pressure of 0.6 MPa for a period of 30 seconds or longer.

[0016] In a preferred aspect of the present invention, the blasting material is ejected under a pressure ranging from 0.4 to 0.65 MPa. According to a preferred aspect of the present invention,

In a preferred aspect of the present invention, the plant blasting material comprises a granular material comprising walnut shells or apricot seeds or peach seeds crushed to a predetermined grain diameter.

In a preferred aspect of the present invention, the predetermined grain diameter of the plating blasting material is in a range from 500 to 700 μm .

[0017] In a preferred aspect of the present invention, the resin blasting material comprises a grain material comprising nylon or polycarbonate or urea resin or melamine resin which is formed into a predetermined grain diameter.

In a preferred aspect of the present invention, the predetermined grain diameter of the resin blasting material is in a range from 420 to 595 μm .

[0018] In a preferred aspect of the present invention, the cleaning method further comprises wetting a surface to be cleaned of the heat transfer tube after removing the scales deposited on the heat transfer tube by ejecting the blasting material to the heat transfer tube; and removing scales deposited on the heat transfer tube by ejecting the blasting material again to the heat transfer tube.

According to the present invention, after the blast cleaning, as a finishing process, the surface to be cleaned is wetted to dissolve water-soluble components in the scales, and then blast cleaning is performed again. By this finishing process, the scales which have been difficult to remove in the first blast cleaning can be easily removed.

In a preferred aspect of the present invention, the surface to be cleaned is wetted by spraying water thereto.

[0019] In a preferred aspect of the present invention, a nozzle unit is used to eject the blasting material to a region where heat transfer tubes are closely arranged in a staggered grid pattern or a straight grid pattern.

[0020] According to a second aspect of the present invention, there is provided a cleaning apparatus for removing scales deposited on a heat transfer tube in a marine boiler by ejecting a blasting material to the heat transfer tube, comprising: a tank filled with a blasting material; a blasting material regulator for pressurizing the blasting material in the tank with compressed air supplied from a compressed air source; and a nozzle unit connected to the blasting material regulator, for ejecting the blasting material together with the compressed air; wherein the blasting material comprises a plant blasting material or a resin blasting material to remove scales deposited on the heat transfer tube and to leave unremoved an oxide film formed on a surface of the heat transfer tube.

According to the present invention, the compressed air is supplied to an upper portion of the tank and also to the blasting material regulator which is disposed at a lower end of the tank. The blasting material in the tank is pressurized by the compressed air and falls into the blasting material regulator, and the blasting material is mixed with the compressed air connected directly to the blasting material regulator and delivered under pressure to the nozzle unit. Then, the blasting material is ejected under a predetermined pressure from the nozzle unit to blast-clean the heat transfer tube. When the heat transfer tube is blast-cleaned by the plant blasting material or the resin blasting material, it is possible to remove only scales from the heat transfer tube without removing an oxide film therefrom. The oxide film formed on the heat transfer tube comprises a dense-structural iron oxide film which is mainly composed of triiron tetraoxide (Fe_3O_4), and is highly wear-resistant and corrosion-resistant. Therefore, the oxide film can protect the base material of the heat transfer tube.

[0021] In a preferred aspect of the present invention, the cleaning method further comprises an atomizer for spraying water to a surface to be cleaned of the heat transfer tube.

According to the present invention, after the blast cleaning, as a finishing process, the surface to be cleaned is wetted with the atomizer, and then blast cleaning is

performed again. By this finishing process, the scales which have been difficult to remove in the first blast cleaning can be easily removed.

[0022] In a preferred aspect of the present invention, the cleaning method further comprises a blasting material drawing duct for drawing the blasting material which has been ejected to the heat transfer tube; a recovery tank for recovering the blasting material drawn by the blasting material drawing duct; and a dust collector connected to the recovery tank, for collecting dust from exhaust air which draws the blasting material.

According to the present invention, the blasting material which has been used is drawn, together with the scales removed from the heat transfer tube, by the blasting material drawing duct which is maintained in a negative pressure, and delivered back to the recovery tank. The blasting material and the scales are classified in the recovery tank. The blasting material is recovered in the recovery tank and reused, and exhaust air containing powdery dust is supplied from the recovery tank to the dust collector. The powdery dust is trapped by the dust collector, and the exhaust air is discharged into the atmosphere.

[0023] In a preferred aspect of the present invention, the nozzle unit uses a soft material in a region which is possibly brought into contact with the heat transfer tube.

The soft material may be aluminum or aluminum alloy, for example.

[0024] In a preferred aspect of the present invention, the nozzle unit comprises a nozzle for ejecting the blasting material and an adapter for holding the nozzle.

According to the present invention, the adapter has a length that is selected depending on the size of a group of heat transfer tubes, so that the nozzle can reach a terminal end of the group of heat transfer tubes.

[0025] In a preferred aspect of the present invention, the adapter is made of aluminum.

According to the present invention, since the adapter is made of a soft material of aluminum, even if the adapter is brought into contact with heat transfer tubes

and structural members in the boiler during the blast cleaning, the adapter will not damage the heat transfer tubes and the structural members.

Advantageous Effects of Invention

[0026] The present invention offers the following advantages:

(1) Since scales deposited on evaporator tubes, superheater tubes, and screen tubes disposed in marine boilers can be removed by blast cleaning, there is no need to use cleaning water, and sulfuric-acid-containing water is not produced. Accordingly, the present invention is effective to solve the problems of sulfuric acid corrosion of the evaporator tubes, the superheater tubes, and the screen tubes, deterioration of the refractory materials, and necessity of treatment of acid waste liquids.

(2) It is possible to remove only scales from the heat transfer tube without removing an oxide film therefrom, by performing blast cleaning using a plant blasting material or a resin blasting material. The oxide film formed on the heat transfer tube comprises a dense-structural iron oxide film which is mainly composed of triiron tetraoxide (Fe_3O_4), and is highly wear-resistant and corrosion-resistant. Therefore, the oxide film can protect the base material of the heat transfer tube.

(3) As evaporator tubes, superheater tubes, and screen tubes disposed in marine boilers may only be blast-cleaned, anyone can safely work on those tubes in an easy-to-use operation, and the safe implementation of the work can be provided for boiler maintenance.

(4) When a plant blasting material is used, even if the blasting material is left in the boiler after the blast cleaning, the blasting material can be burned when the boiler is in operation. Inasmuch as the plant material is used, the blast cleaning can be performed without imposing load on the environment.

(5) After the blast cleaning, as a finishing process, the surface to be cleaned is wetted, and then blast cleaning is performed again. By this finishing process,

the scales which have been difficult to remove in the first blast cleaning can be easily removed.

Brief Description of Drawings

[0027] Fig. 1 is a vertical cross-sectional view of a marine boiler to which a method and apparatus for cleaning a heat transfer tube in a marine boiler according to the present invention is applied;

Fig. 2 is a horizontal cross-sectional view of a marine boiler;

Fig. 3 is a schematic view showing an apparatus for cleaning a heat transfer tube in a marine boiler according to an embodiment of the present invention;

Fig. 4 is a perspective view showing details of a blast nozzle unit;

Fig. 5A is an image captured of superheater tubes disposed in a marine boiler before scales deposited on the outer surfaces of the superheater tubes are removed;

Fig. 5B is an image showing the surface state of superheater tubes after the superheater tubes are processed by blast cleaning, showing some scales left unremoved though most scales have been removed;

Fig. 5C is an image captured of the superheater tubes after scales deposited on the outer surfaces of the superheater tubes are removed by blast cleaning; and

Fig. 6 is a graph showing results of operations of a marine boiler, showing steam temperatures at the outlet of a superheater of the boiler vs. amounts of evaporation (boiler loads) in the boiler.

Description of Embodiments

[0028] A method and apparatus for cleaning a heat transfer tube in a marine boiler according to an embodiment of the present invention will be described below with reference to Figs. 1 through 6. In Figs. 1 through 6, identical or corresponding

components or elements are denoted by identical reference characters, and any redundant descriptions thereof will be omitted.

Fig. 1 is a vertical cross-sectional view of a marine boiler to which a method and apparatus for cleaning a heat transfer tube in a marine boiler according to the present invention is applied, and Fig. 2 is a horizontal cross-sectional view of the marine boiler. As shown in Figs. 1 and 2, a marine boiler has a steam drum 1, screen tubes 2, superheater tubes 3, a water drum 4, evaporator tubes 6, and the like. The marine boiler has access holes 5 defined in an outer wall thereof for the operator to go into and out of the marine boiler therethrough (in Fig. 1, only one access hole 5 is illustrated).

[0029] The method and apparatus for cleaning a heat transfer tube in a marine boiler according to the present invention is applied to the removal of scales deposited on heat transfer tubes such as the screen tubes 2, the superheater tubes 3, and the evaporator tubes 6. The screen tubes 2, the superheater tubes 3, and the evaporator tubes 6 will hereinafter be collectively referred to as “heat transfer tubes”.

[0030] Fig. 3 is a schematic view showing the apparatus for cleaning a heat transfer tube in a marine boiler according to the embodiment of the present invention. The apparatus for cleaning a heat transfer tube in a marine boiler according to the present invention comprises a blast cleaning apparatus for removing scales deposited on the heat transfer tubes by blowing a blasting material to the heat transfer tubes. As shown in Fig. 3, the blast cleaning apparatus 10 has a compressor 11, a blasting apparatus 12, and a blast nozzle unit 13. The compressor 11 and the blasting apparatus 12 are connected to each other by a pressure-resistant hose 14. The blasting apparatus 12 and the blast nozzle unit 13 are connected to each other by a blast hose 15. The blasting apparatus 12 includes a pressurization tank 121 filled with a blasting material, a recovery tank 122 for recovering the blasting material that has been used, and a filter 123. A gravity-type valve (not shown) is disposed between the pressurization tank 121 and the recovery tank 122. The pressurization tank 121 has a lower end connected to an ejector 124. The recovery tank 122 and the filter 123 are connected to each other by a hose 125.

[0031] The blasting apparatus 10 constructed as shown in Fig. 3 operates as follows: Compressed air pressurized by the compressor 11 is supplied through the pressure-resistant hose 14 to an upper portion of the pressurization tank 121 and the ejector 124 provided at the lower end of the pressurization tank 121. As a result, the blasting material in the pressurization tank 121 is pressurized by the compressed air, and is drawn by a negative pressure developed by the ejector 124. Thus, the blasting material is delivered under pressure from the ejector 124 through the blast hose 15 to the blast nozzle unit 13. The blasting material is then ejected under a predetermined pressure from the blast nozzle unit 13 to blast-clean an object to be cleaned. The blasting material that has been used, and scales removed from the heat transfer tubes are drawn by a blasting material drawing duct 16 that is kept under a negative pressure, and delivered back to the blasting apparatus 12. The blasting material and the scales are classified in the recovery tank 122 of the blasting apparatus 12. The blasting material is recovered in the recovery tank 122 and reused, and exhaust air containing powdery dust is supplied from the recovery tank 122 through the hose 125 to the filter 123. The powdery dust is trapped by the filter 123 serving as a dust collector, and the exhaust air is discharged into the atmosphere.

[0032] Fig. 4 is a perspective view showing details of the blast nozzle unit 13. As shown in Fig. 4, the blast nozzle unit 13 has a nozzle 131 for ejecting the blasting material and an adapter tube 132 connected to the nozzle 131. The nozzle 131 and the adapter tube 132 are connected by threaded engagement with each other. Specifically, the nozzle 131 has a female PT thread and the adapter tube 132 has a male PT thread, and the nozzle 131 and the adapter tube 132 are connected with each other by threaded engagement. The nozzle 131 has ejection ports 131n for ejecting the blasting material therethrough. In the embodiment shown in Fig. 4, each of the ejection ports 131n has a diameter of 7 mm and has an ejection angle of 90°, i.e., extends in a direction perpendicular to the longitudinal (axial) direction of the nozzle 131. As indicated by a

two-dot-and-dash line, the ejection port 131n may be defined so as to be open in the longitudinal (axial) direction of the nozzle 131.

[0033] The adapter tube 132 including the nozzle 131 has a length ranging from 300 mm to 500 mm. The adapter tube 132 comprises an aluminum tube. Since the adapter tube 132 is made of aluminum, the Vickers hardness thereof can be kept at 120 or less. Therefore, even if the adapter tube 132 is brought into contact with the heat transfer tubes and structural members in the boiler during the blast cleaning, the adapter tube 132 will not damage the heat transfer tubes and the structural members.

[0034] The nozzle 131 and the adapter tube 132 have substantially the same outside diameter, which is small enough to be inserted in a group of tubes including the superheater tubes 3 and the evaporator tubes 6. According to the present embodiment, the outside diameter of the nozzle 131 and the adapter tube 132 is in the range from 17 mm to 19 mm. The length of the adapter tube 132 is set to a value ranging from 300 mm to 500 mm, for example, which is large enough to reach the terminal end of the group of tubes including the superheater tubes 3 and the evaporator tubes 6. Further, a blasting material supply hole defined in the nozzle 131 in fluid communication with the ejection ports 131n has an inside diameter that is the same as the inside diameter of a blasting material supply hole defined in the adapter tube 132. The inside diameter of the blasting material supply hole is substantially the same as or greater than the inside diameter of the ejection port 131n.

[0035] The blasting material used in the present invention will be described below.

Generally, blasting materials used in the blast cleaning include hard-type blasting materials, semi-hard-type blasting materials, and soft-type blasting materials. The hard-type blasting materials include metal blasting materials and ceramic blasting materials. The semi-hard-type blasting materials include glass blasting material and metal blasting materials. The soft-type blasting materials include resin blasting materials and plant blasting materials.

Heat transfer tubes for marine boilers which are to be cleaned according to the present invention were blast-cleaned using various blasting materials including ceramic, metal, glass, resin, and plant blasting materials. The names (commercial names) of the blasting materials used, hardnesses, specific gravities, grain diameters, ejection pressures at the time of the blast cleaning, and cleaning results are shown in Table 1. In Table 1, the ranges of grain diameters represent ranges between minimum and maximum grain diameters, with the grains being sifted out. The heat transfer tubes for marine boilers which are to be blast-cleaned were superheater tubes. Specifically, superheater tubes comprising alloy steel tubes made of “STBA22” and “KA-STBA28” were blast-cleaned. Here, the phrase “Base material exposed” in Table 1 means that scales and the oxide film formed on the surface of the heat transfer tube were removed, exposing the material of the heat transfer tube.

[0036]

Table 1

	Blasting material		New Mohs hardness	Bulk specific gravity	True specific gravity	Grain diameter (μm)	Pressure (MPa)	Results of cleaning
Test example 1	Ceramic	Alundum #46	12.0	1.95	3.93	300 - 350	0.5	Base material exposed
		Alundum #80				150 - 180		
Test example 2	Metal	Reduced iron powder	4.5	3.50	7.20	177 - 200	0.5	Base material partly exposed
		SUS cut wire	6.0	4.46	7.60	ϕ 400 $\times$ L400	0.3	
Test example 3	Glass	Glass beads #80	6.5	1.60	2.50	180 - 250	0.3, 0.5	Base material partly exposed when ejected at one location for 5 seconds or longer
		Glass beads #150				106 - 125	0.2, 0.3	
		Glass beads #300				53 - 63	0.2	
Test example 4	Resin	POLYPLUS (type III) #30 - 40	4.0	0.95	1.50	420 - 595	0.5, 0.6, 0.65	Only scales removed
Test example 5	Plant	Walnut #30	3.0	0.58	1.28	500 - 700	0.4, 0.65	Only scales removed
		Peach #30	4.0	0.74	1.41		0.6	

[0037] Test examples 1 through 5 will be described below with reference to Table 1.

As shown in Test example 1, when a ceramic blasting material was used, the grinding force was strong enough to remove scales from the heat transfer tube and to grind the base material of the heat transfer tube. Therefore, the ceramic blasting material was not suitable as a blasting material for use in blast cleaning for marine boilers.

In Test example 2, a metal blasting material was used. In this case, the metal blasting material had a grinding force smaller than the ceramic blasting material in Test example 1. However, the base material of the heat transfer tube was partly exposed, and because the blasting material was metal, it was necessary to take into account contact between the metal of the heat transfer tube and the metal of the blasting material, tending to cause corrosion due to contact between different metals. Thus, the metal blasting material was not suitable for use as a blasting material.

In Test example 3, a glass blasting material was used. The glass blasting material had a grinding force which was essentially the same as the grinding force of the metal blasting material in Test example 2. However, inasmuch as the ejection pressure needed to be kept low (0.3 MPa or lower) in order to prevent the base material from being exposed and time management was necessary to keep the blast cleaning time for one location short (5 seconds or shorter for one location), the glass blasting material was not suitable for use as a blasting material.

[0038] In Test example 4, POLYPLUS (registered trademark) # 30 to 40 of urea resin and Type III POLYHARD (registered trademark) # 30 to 40 of melamine resin were used as resin blasting materials, and blast cleaning was carried out using ejection pressures of 0.5 MPa, 0.6 MPa, and 0.65 MPa. The blasting materials in Test example 4 were optimum as blasting materials for use in blast cleaning for marine boilers. Specifically, only scales on the heat transfer tube were removed, and the oxide film on the heat transfer tube remained unremoved and the base material was unexposed.

In Test example 5, a plant blasting material # 30 of walnut was used, and blast cleaning was carried out using ejection pressures of 0.45 MPa and 0.65 MPa. As a result, only scales were removed from the heat transfer tube, and the oxide film remained unremoved on the heat transfer tube and the base material was unexposed. In Test example 5 also, a plant blasting material # 30 of peach was used, and blast cleaning was carried out using an ejection pressure of 0.6 MPa. As a result, only scales were removed from the heat transfer tube, and the oxide film remained unremoved on the heat transfer tube and the base material was unexposed. The plant blasting materials were optimum as blasting materials for use in blast cleaning for marine boilers.

Here, “walnut” used as a plant blasting material refers to an abrasive material comprising walnut shells as nuts crushed to grains having a desired grain size, and “peach” refers to an abrasive material comprising peach seeds as fruit processed in the same manner.

[0039] Figs. 5A through 5C are images captured of superheater tubes disposed in a marine boiler before and after scales on the outer surfaces of the superheater tubes are removed. The superheater tubes with scales deposited thereon were actually used in a marine boiler, and are made of STBA22. The superheater tubes were blast-cleaned using a plant blasting material at an ejection pressure of 0.6m MPa.

Fig. 5A shows the surfaces of superheater tubes before the superheater tubes are blast-cleaned, illustrating thick layers of scales deposited on the surfaces. Fig. 5B shows the surfaces of the superheater tubes after the superheater tubes are blast-cleaned, illustrating some scales left unremoved though most scales have been removed. Fig. 5C shows the surfaces of the superheater tubes after the superheater tubes are finished by blast cleaning subsequent to the blast cleaning shown in Fig. 5B. Specifically, in Fig. 5C, almost all scales are removed, with the oxide film being left unremoved.

The blast cleaning as the above finishing process is a process of blast-cleaning the surfaces again after the surfaces are wetted subsequently to the first blast

cleaning. The blast-cleaned surfaces are wetted by water sprayed by an atomizer or the like after the first blast cleaning.

It is considered that a sulfur oxide which is one of the major constituents of the scales that remain on the blast-cleaned surfaces reacts with water, thus producing a water-soluble substance that makes the remaining scales brittle, and hence the remaining scales are easily removed.

[0040] Fig. 6 is a graph of results of operations of a marine boiler, showing steam temperatures at the outlet of a superheater of the boiler vs. amounts of evaporation (boiler loads) in the boiler.

In Fig. 6, solid lozenge-shaped dots represent data obtained when the marine boiler has operated on a test run. Specifically, the solid lozenge-shaped dots illustrate results of an operation of the marine boiler in such a state that no scales are deposited on the superheater tubes in the marine boiler. It can be seen from the solid lozenge-shaped dots that after the amount of evaporation (boiler load) in the marine boiler has reached 70 %, the steam temperature at the outlet of the superheater is kept at 515°C (set temperature).

In Fig. 6, solid square-shaped dots represent data obtained after the marine boiler has operated for a predetermined period. When the amount of evaporation (boiler load) in the marine boiler reaches 70 %, the steam temperature at the outlet of the superheater does not reach 480°C, and even when the boiler load is 90 %, the steam temperature at the outlet of the superheater does not reach the set temperature of 515°C.

In Fig. 6, dots indicated by Δ and $\times$ show results of operations of different marine boilers to which the blast cleaning of the present invention is applied.

The data represented by the dots indicated by Δ were obtained when blast cleaning was carried out using walnut as a blasting material and at an ejection pressure of 0.5 MPa. The data represented by the dots indicated by $\times$ were obtained when blast cleaning was carried out using walnut as a blasting material and at an ejection pressure of 0.5 MPa.

It can be seen from the dots indicated by Δ and $\times$ shown in Fig. 6 that after the marine boilers were blast-cleaned, the steam temperature at the outlet of the superheater reaches the set temperature of 515°C when the boiler load reaches 70 %. Therefore, the marine boilers that have been blast-cleaned according to the present invention can recover their operation efficiency. Further, the steam temperature at the outlet of the superheater is recovered, and hence the amount of the consumed fuel can be greatly reduced.

[0041] The present invention is not limited to the embodiment as described above. It should be noted that various modification and other embodiments can be made within technical concept defined by claims, specification, and drawings.

Industrial Applicability

[0042] The present invention is applicable to a method and apparatus for removing scales from the outer surfaces of evaporator tubes, superheater tubes, and screen tubes disposed in boilers which are installed on marine vessels.

Reference Signs List

- [0043]
- 1 steam drum
 - 2 screen tube
 - 3 superheater tube
 - 4 water drum
 - 5 access hole
 - 6 evaporator tube
 - 10 blast cleaning apparatus
 - 11 compressor
 - 12 blasting apparatus
 - 13 blast nozzle unit
 - 14 pressure-resistant hose

15 blast hose
16 blasting material drawing duct
121 pressurization tank
122 recovery tank
123 filter
124 ejector
125 hose
131 nozzle
131n ejection port
132 adapter tube

CLAIMS

[Claim 1] A cleaning method of removing scales deposited on a heat transfer tube in a marine boiler by ejecting a blasting material to the heat transfer tube, comprising:

removing scales deposited on said heat transfer tube by using a plant blasting material or a resin blasting material as a blasting material; and

leaving unremoved an oxide film formed on a surface of said heat transfer tube.

[Claim 2] A cleaning method according to claim 1, wherein said blasting material is ejected under a pressure ranging from 0.4 to 0.65 MPa.

[Claim 3] A cleaning method according to claim 1, wherein said plant blasting material comprises a granular material comprising walnut shells or apricot seeds or peach seeds crushed to a predetermined grain diameter.

[Claim 4] A cleaning method according to claim 3, wherein said predetermined grain diameter of said plating blasting material is in a range from 500 to 700 μm .

[Claim 5] A cleaning method according to claim 1, wherein said resin blasting material comprises a grain material comprising nylon or polycarbonate or urea resin or melamine resin which is formed into a predetermined grain diameter.

[Claim 6] A cleaning method according to claim 5, wherein said predetermined grain diameter of said resin blasting material is in a range from 420 to 595 μm .

[Claim 7] A cleaning method according to any one of claims 1 through 6, further comprising:

wetting a surface to be cleaned of said heat transfer tube after removing the scales deposited on said heat transfer tube by ejecting the blasting material to said heat transfer tube; and

removing scales deposited on said heat transfer tube by ejecting the blasting material again to said heat transfer tube.

[Claim 8] A cleaning method according to claim 7, wherein said surface to be cleaned is wetted by spraying water thereto.

[Claim 9] A cleaning method according to claim 1, wherein a nozzle unit is used to eject said blasting material to a region where heat transfer tubes are closely arranged in a staggered grid pattern or a straight grid pattern.

[Claim 10] A cleaning apparatus for removing scales deposited on a heat transfer tube in a marine boiler by ejecting a blasting material to the heat transfer tube, comprising:

a tank filled with a blasting material;

a blasting material regulator for pressurizing said blasting material in said tank with compressed air supplied from a compressed air source; and

a nozzle unit connected to said blasting material regulator, for ejecting said blasting material together with the compressed air;

wherein said blasting material comprises a plant blasting material or a resin blasting material to remove scales deposited on said heat transfer tube and to leave unremoved an oxide film formed on a surface of said heat transfer tube.

[Claim 11] A cleaning apparatus according to claim 10, further comprising:

an atomizer for spraying water to a surface to be cleaned of said heat transfer tube.

[Claim 12] A cleaning apparatus according to claim 10, further comprising:
 a blasting material drawing duct for drawing the blasting material which
has been ejected to said heat transfer tube;
 a recovery tank for recovering the blasting material drawn by said
blasting material drawing duct; and
 a dust collector connected to said recovery tank, for collecting dust from
exhaust air which draws the blasting material.

[Claim 13] A cleaning apparatus according to claim 10, wherein said nozzle unit uses
a soft material in a region which is possibly brought into contact with said heat transfer
tube.

[Claim 14] A cleaning apparatus according to claim 10, wherein said nozzle unit
comprises a nozzle for ejecting said blasting material and an adapter for holding said
nozzle.

[Claim 15] A cleaning apparatus according to claim 14, wherein said adapter is made
of aluminum.