US 20170198909A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2017/0198909 A1

(43) Pub. Date: Jul. 13, 2017

FUKAI

(54) DEVICE FOR SUPPLYING EMULSIFIED FUEL AND METHOD FOR SUPPLYING SAID FUEL

(71) Applicant: **Toshiharu FUKAI**, Nagano (JP)

(72) Inventor: **Toshiharu FUKAI**, Nagano (JP)

(21) Appl. No.: **15/320,652**

(22) PCT Filed: **Jun. 23, 2015**

(86) PCT No.: **PCT/JP2015/068052**

§ 371 (c)(1),
(2) Date: **Dec. 20, 2016**

(30) **Foreign Application Priority Data**

Jun. 24, 2014 (JP) 2014-128944
Jul. 15, 2014 (JP) 2014-145254

Publication Classification

(51) **Int. Cl.**

F23K 5/12 (2006.01)
F23K 5/14 (2006.01)
C10L 1/32 (2006.01)

(52) **U.S. Cl.**

CPC ***F23K 5/12*** (2013.01); ***C10L 1/328*** (2013.01); ***F23K 5/147*** (2013.01); *C10L 2250/082* (2013.01); *C10L 2200/0469* (2013.01); *F23K 2301/10* (2013.01)

(57) **ABSTRACT**

Provided are an emulsion fuel supply device capable of stably driving a combustion apparatus with a simple device configuration, and a supply method of an emulsion fuel. A device **1** is a device for supplying the emulsion fuel to a combustion apparatus **70**, including a processed water generation device **10** for removing Ca and Mg ions from raw water and allowing to remain or adding Na ions in the raw water, tanks **20** and **30**, a section for merging a fuel oil from the tank **30** and processed water from the tank **20**, a section **50** for producing the emulsion fuel from a mixture of the merged fuel oil and processed water, and a section for supplying the emulsion fuel to the combustion apparatus **70**.

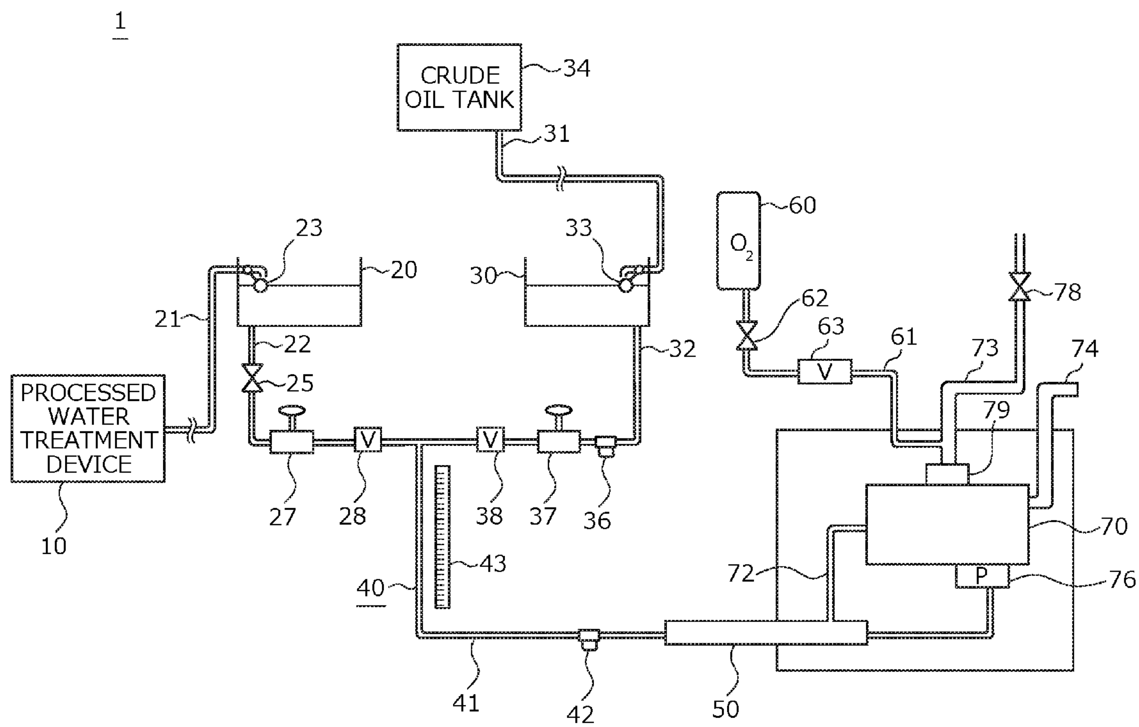


FIG. 1

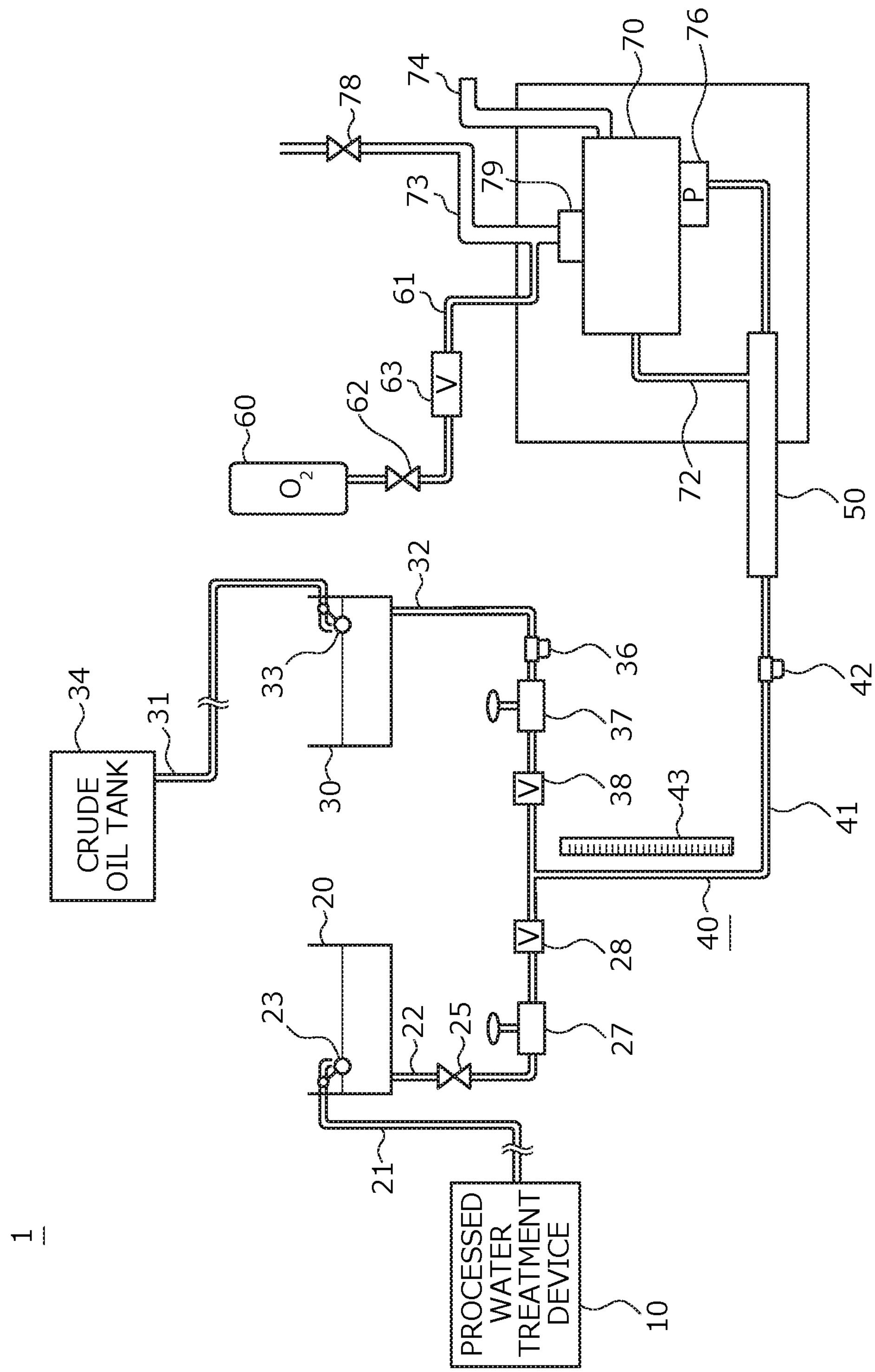

1
PROCESSED WATER TREATMENT DEVICE
10
21
22
23
25
27
28
20
CRUDE OIL TANK
34
31
33
30
32
36
37
38
40
41
42
43
50
O2
60
62
63
V
V
V
61
72
73
78
79
70
74
76
P

FIG. 2

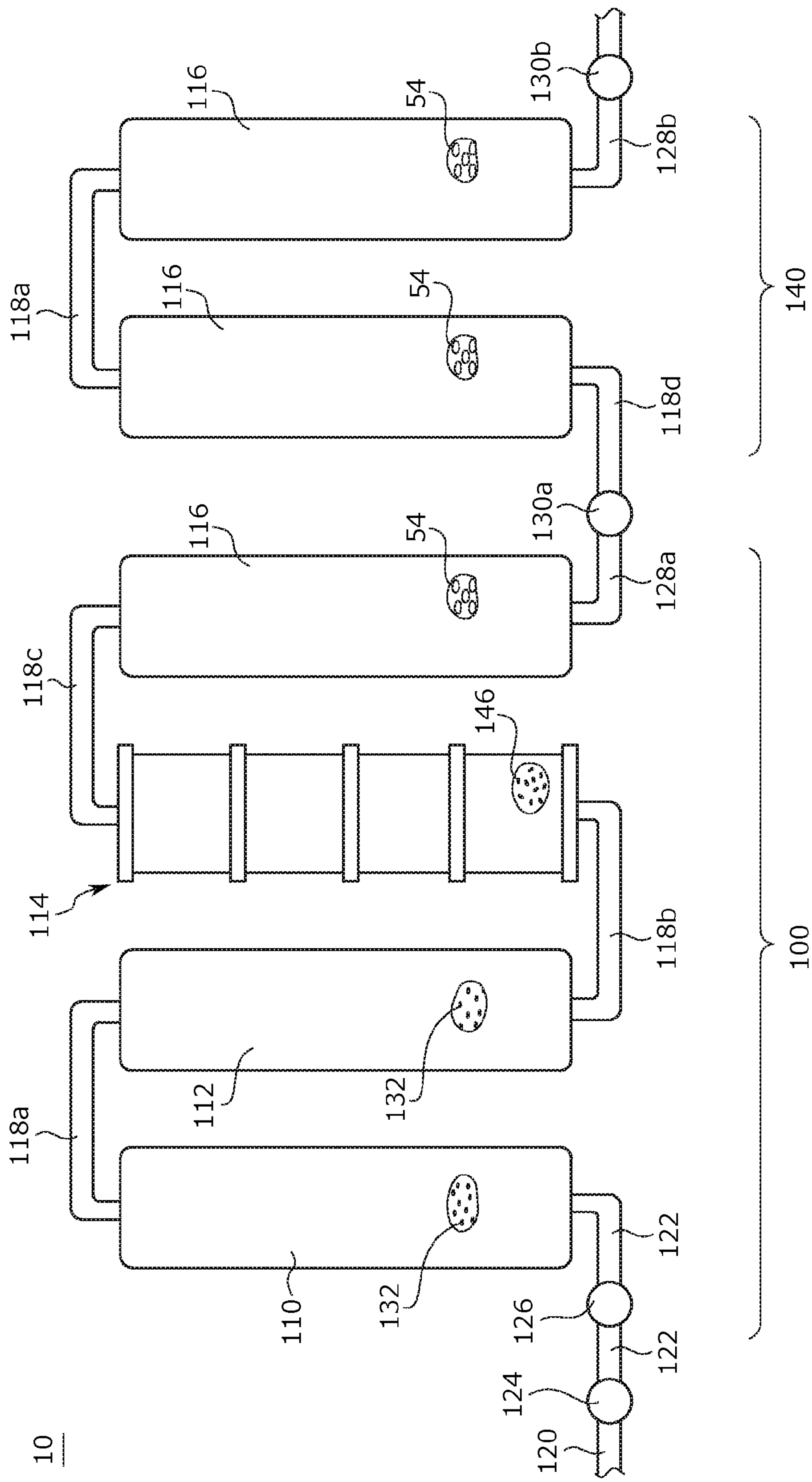

10
100
110
112
114
116
116
116
118a
118a
118b
118c
118d
120
122
122
124
126
128a
128b
130a
130b
132
132
140
146
54
54
54

FIG. 3

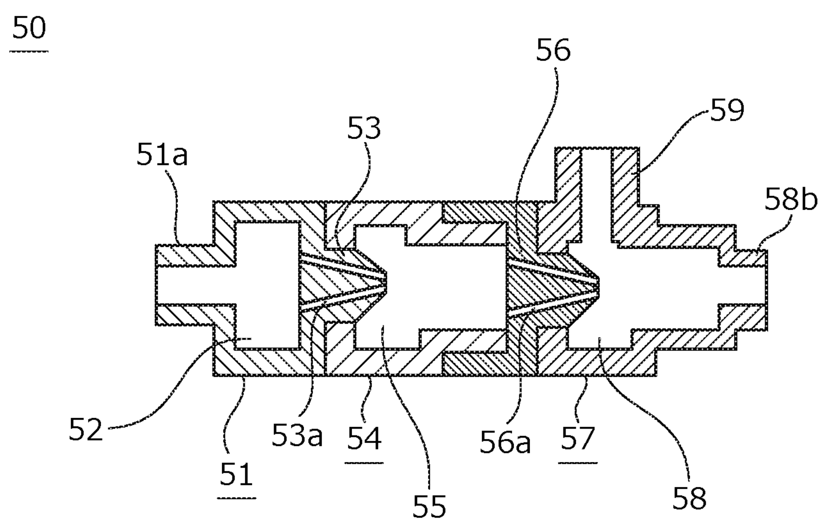


FIG. 4

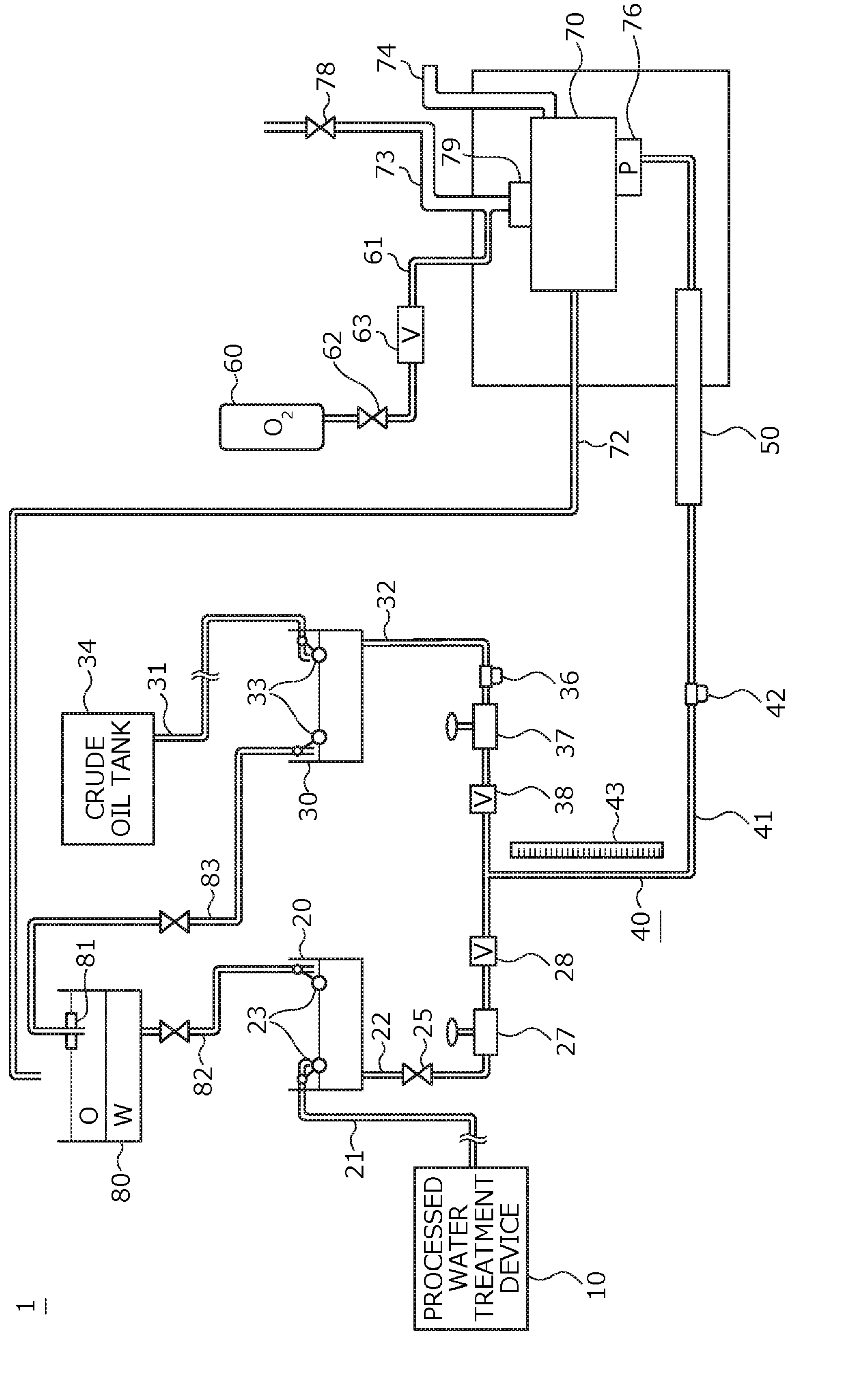

1
PROCESSED WATER TREATMENT DEVICE
10
CRUDE OIL TANK
34
O
W
80
81
82
83
21
22
23
20
25
27
28
30
31
32
33
36
37
38
40
41
42
43
50
60
O_2
61
62
63
V
V
V
70
72
73
74
76
P
78
79

FIG. 5

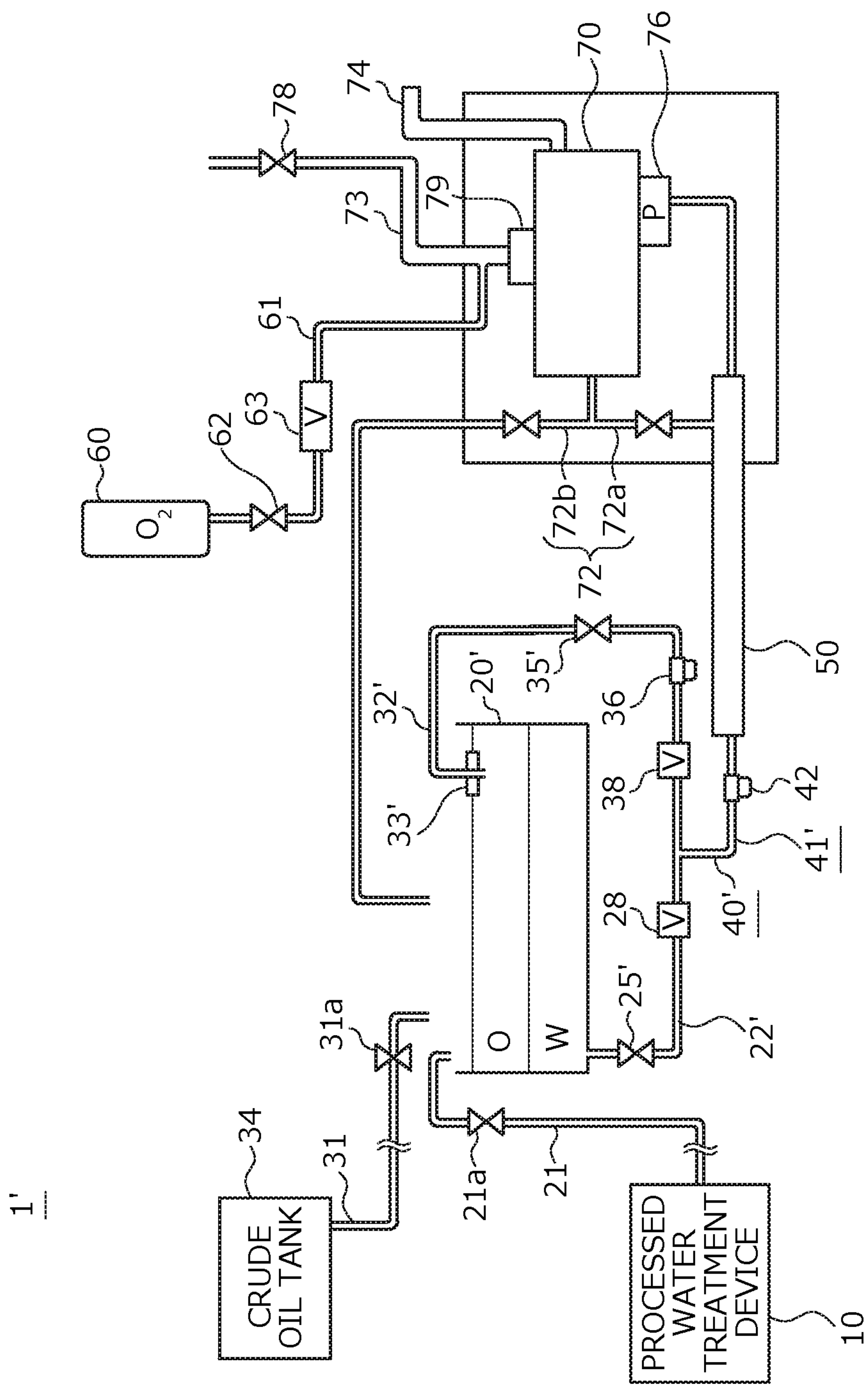

1'
CRUDE OIL TANK
PROCESSED WATER TREATMENT DEVICE
O
W
O_2
V
P
10
21
21a
22'
25'
20'
28
31
31a
32'
33'
34
35'
36
38
40'
41'
42
50
60
61
62
63
70
72
72a
72b
73
74
76
78
79

FIG. 6

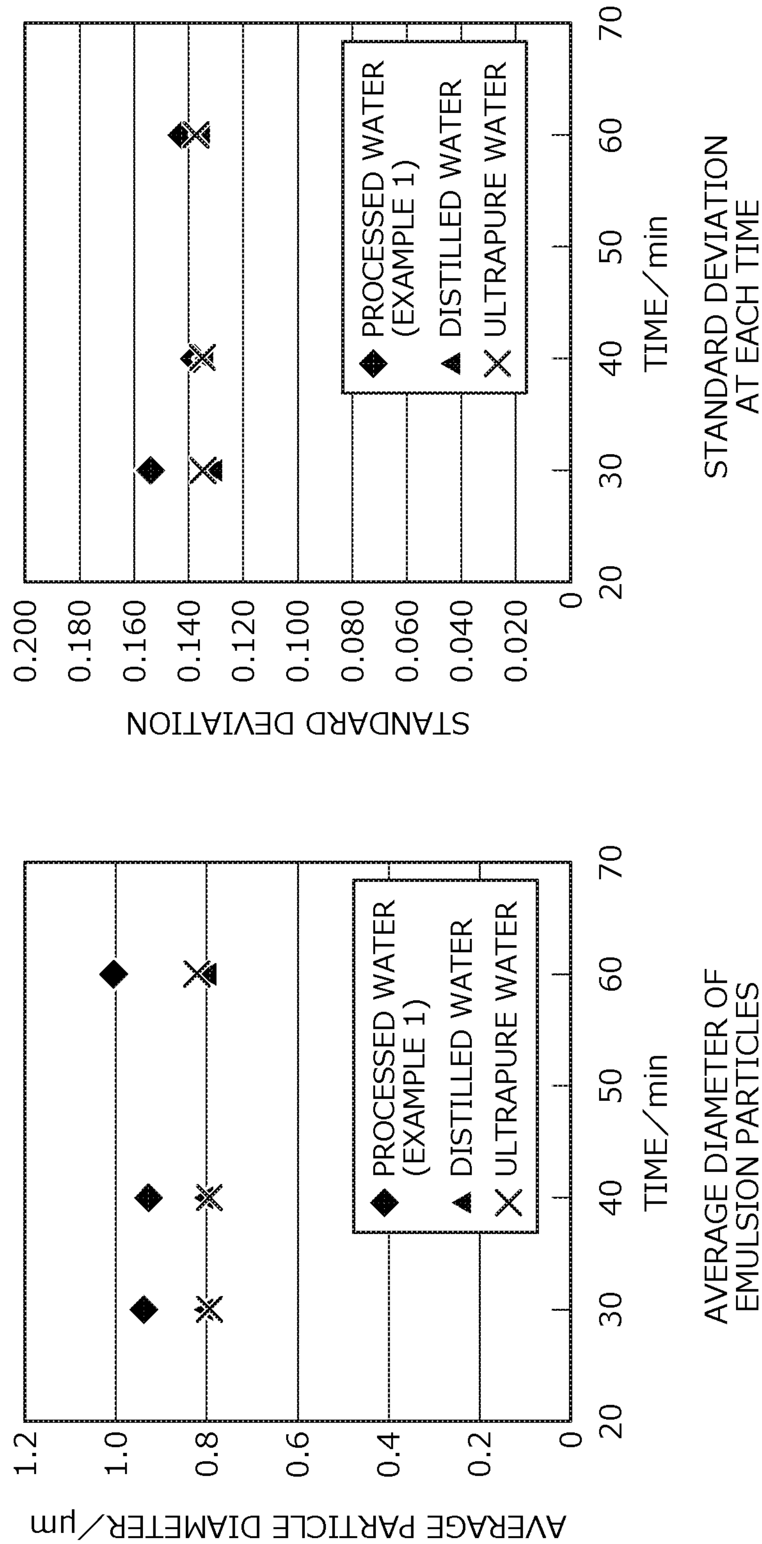

STANDARD DEVIATION
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0
20
30
40
50
60
70
TIME／min
PROCESSED WATER (EXAMPLE 1)
DISTILLED WATER
ULTRAPURE WATER
STANDARD DEVIATION AT EACH TIME
AVERAGE PARTICLE DIAMETER／μm
1.2
1.0
0.8
0.6
0.4
0.2
0
20
30
40
50
60
70
TIME／min
PROCESSED WATER (EXAMPLE 1)
DISTILLED WATER
ULTRAPURE WATER
AVERAGE DIAMETER OF EMULSION PARTICLES

FIG. 7

WATER TEMPERATURE : 26.0℃ SURFACE TENSION UNIT mN/m^{-1}

ULTRAPURE WATER		EXAMPLE 2 ION GENERATOR 30 MIN.		EXAMPLE 5 OBSIDIAN 30 MIN.	
MEASUREMENT VALUE	AVERAGE VALUE	MEASUREMENT VALUE	AVERAGE VALUE	MEASUREMENT VALUE	AVERAGE VALUE
71.3	71.3	71.3	71.4	71.8	71.8
71.3		71.4		71.8	
71.4		71.4		71.7	
71.3		71.4		71.7	

EXAMPLE 3 ION GENERATOR 1 HR.		EXAMPLE 6 OBSIDIAN 1 HR.	
MEASUREMENT VALUE	AVERAGE VALUE	MEASUREMENT VALUE	AVERAGE VALUE
71.2	71.3	71.4	71.4
71.3		71.4	
71.3		71.4	
71.3		71.3	

EXAMPLE 4 ION GENERATOR 3 HRS.		EXAMPLE 7 OBSIDIAN 3 HRS.	
MEASUREMENT VALUE	AVERAGE VALUE	MEASUREMENT VALUE	AVERAGE VALUE
71.1	71.2	63.7	63.6
71.2		63.6	
71.2		63.6	
71.1		63.6	

EXAMPLE 8 OBSIDIAN 4 HRS.	
MEASUREMENT VALUE	AVERAGE VALUE
71.4	71.4
71.4	
71.5	
71.4	

EXAMPLE 9 OBSIDIAN 5 HRS.	
MEASUREMENT VALUE	AVERAGE VALUE
67.7	67.7
67.6	
67.7	
67.7	

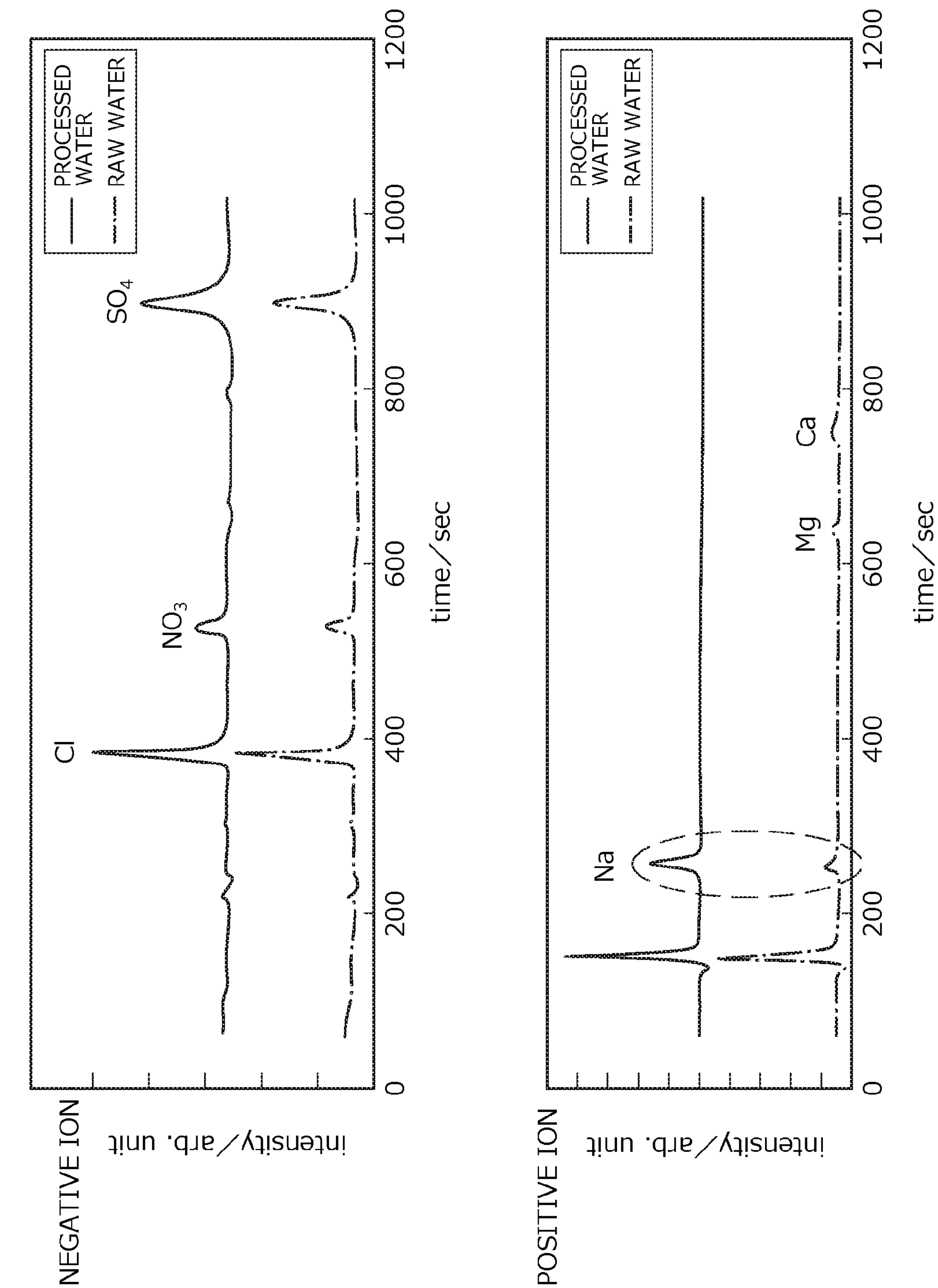
FIG. 8

MEASUREMENT TEMPERATURE : 26℃
SURFACE TENSION UNIT : mN/m

ULTRAPURE WATER	RAW WATER (TAP WATER)	EXAMPLE 10 OBSIDIAN 5 HRS.
71.1	64.9	69.1
71.0	65.0	69.0
71.2	64.9	69.0
71.2	64.9	69.9

EXAMPLE 11 ENDLESS PROCESSED WATER	SURFACTANT-ADDED TAP WATER
67.2	26.0
67.1	26.0
67.4	26.0
67.4	26.0
67.4	26.0
67.4	26.0

FIG. 9


NEGATIVE ION
intensity/arb. unit
PROCESSED WATER
RAW WATER
Cl
NO3
SO4
0
200
400
600
800
1000
1200
time/sec
POSITIVE ION
intensity/arb. unit
PROCESSED WATER
RAW WATER
Na
Mg
Ca
0
200
400
600
800
1000
1200
time/sec

DEVICE FOR SUPPLYING EMULSIFIED FUEL AND METHOD FOR SUPPLYING SAID FUEL

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is entering into national phase of PCT Application No. PCT/JP2015/068052, filed on Jun. 23, 2015, which claims the priority from Japanese Patent Application No. 2014-128944, filed on Jun. 24, 2014, and Japanese Patent Application No. 2014-145254, filed on Jul. 15, 2014 in the Japanese Patent Office. The entire contents of which are hereby incorporated by reference into this application.

TECHNICAL FIELD

[0002] The present invention is related to an emulsion fuel supply device for supplying an emulsion fuel obtained by emulsifying a fuel oil and water to a combustion apparatus and a supply method of the same.

BACKGROUND ART

[0003] It is conventionally known that an emulsion fuel obtained by mixing water, a fuel oil, such as gasoline, light oil, kerosene, heavy oil, vegetable oil, and waste oil, and an emulsifier produces little nitrogen oxide (NOX) and soot in combustion, thus being an effective fuel for preventing air pollution. Further, since the fuel is mixed with water, a ratio of the fuel fed to a combustion apparatus drops by a mixing amount of the water, which, in theory, can cause a reduction of fuel cost.

[0004] Therefore, various methods of producing an emulsion fuel and supply devices to a combustion apparatus have been proposed (e.g., Patent Document 1).

[0005] Patent Document 1 discloses an emulsion fuel system including a fuel oil tank for storing a fuel oil, a water tank for storing water, an emulsion generation unit for producing an emulsion fuel substantially composed of the fuel oil and water from the fuel oil supplied from the fuel oil tank and the water supplied from the water tank, and a power generator in which the emulsion fuel produced in the emulsion generation unit is introduced and burned. The emulsion generation unit has two or more emulsion generation devices that produce the emulsion fuel from the fuel oil and the water, and the emulsion fuel is produced in at least one of the two or more emulsion generation devices using the fuel oil supplied from the fuel oil tank and the water supplied from the water tank. The power generator is driven by burning the emulsion fuel continuously produced in the emulsion generation unit.

[0006] According to the emulsion fuel system of Patent Document 1, the emulsion fuel can be produced without using an emulsifier, and a production quantity of the emulsion fuel can be changed as necessary without the need for storing the produced emulsion fuel and without increasing pressure loss of the system.

CITATION LIST

Patent Document

[0007] PATENT DOCUMENT 1: JP 2011-122035 A

SUMMARY OF INVENTION

Technical Problem

[0008] However, the invention of Patent Document 1 uses water not applied with a special treatment, thus energy efficiency of the produced emulsion fuel is low and energy obtained from the power generator is reduced by an amount corresponding to a mixture ratio of the water. As such, there is little merit in using the emulsion fuel instead of the fuel oil. Furthermore, because the produced emulsion fuel has low energy efficiency, the operation of the power generator is not stabilized and a misfire occurs in the power generator, thereby easily causing engine stalling.

[0009] Further, in the invention of Patent Document 1, in order to control a fluctuation of loads on the power generator caused by lack of an emulsifier, a plurality of the emulsion generation devices are connected in parallel and the number of the emulsion generation devices in operation is suitably increased or decreased corresponding to the loads of the power generator. This requires, in each of the emulsion generation devices, a valve for switching between use and disuse and a discarding pipe for discarding a mixture of a fuel and water subjected to an oil-water separation treatment inside of the emulsion generation devices of which operation is temporarily suspended, thus making a device configuration complicated.

[0010] Among emulsion fuel supply devices in which no emulsifier is added, there is no known device that is capable of stably driving a combustion apparatus, and yet having a simple device configuration.

[0011] The present invention was made in view of the problems described above, and it is an object thereof to provide an emulsion fuel supply device capable of stably driving a combustion apparatus with a simple device configuration, and a supply method thereof.

[0012] Another object of the present invention is to provide an emulsion fuel supply device capable of supplying an emulsifier-free emulsion fuel that has high combustion efficiency in a combustion apparatus, and a supply method thereof.

Solution to Problem

[0013] The problems described above can be solved according to an emulsion fuel supply device of the present invention. The device is for supplying an emulsion fuel having an aqueous phase and an oil phase of a fuel oil to a combustion apparatus and includes: a processed water generation device for producing processed water by removing, from raw water, Ca ions and Mg ions contained in the raw water and allowing to remain or adding Na ions in the raw water; a tank for storing the processed water supplied from the processed water generation device and the fuel oil; a merging section for merging the fuel oil supplied from the tank and the processed water supplied from the tank at a predetermined flow rate ratio; an emulsion generation section for producing the emulsion fuel from a mixture of the fuel oil and the processed water merged by the merging section; and a supply section for supplying the emulsion fuel produced by the emulsion generation section to the combustion apparatus.

[0014] In this manner, a raw material of the emulsion fuel in use is the processed water produced by removing, from raw water, Ca ions and Mg ions contained in the raw water and allowing to remain or adding Na ions in the raw water, thus the emulsion fuel can be produced by using the processed water containing highly active atomic hydrogen, making it possible to supply the emulsion fuel of high energy efficiency.

[0015] Further, using the processed water makes it possible to perform emulsification with the fuel oil without using an emulsifier, thus an emulsifier-free emulsion fuel can be achieved.

[0016] Moreover, the emulsion fuel of the present invention uses the processed water made of soft water from which Ca ions and Mg ions are removed as a raw material, and also does not contain an emulsifier, thus oxidation, rust and corrosion in a combustion apparatus can be suppressed and the deterioration of a combustion apparatus caused by the emulsion fuel can be suppressed.

[0017] In this configuration, the tank may be a single tank storing the processed water and the fuel oil, including a water supply pipe having a liquid suction port arranged near a bottom part of the tank and an oil supply pipe having a liquid suction port attached on a float floating on the surface of a liquid stored in the tank, and the merging section may alternately perform a supply of the processed water from the water supply pipe and a supply of the fuel oil from the oil supply pipe to merge the fuel oil and the processed water.

[0018] With such a configuration, it is not necessary to prepare a plurality of tanks for the processed water and the fuel oil, making a device configuration simple. As such, it is not necessary to add a new tank for the processed water to the existing fuel supply device, making it easy to introduce the emulsion fuel supply device of the present invention.

[0019] In this configuration, the tank may include a water tank for storing the processed water supplied from the processed water generation device and a fuel oil tank for storing the fuel oil, formed as a separate part from the water tank, and include an in-tank liquid height adjusting device for adjusting the difference between the height from a bottom surface of the fuel oil tank to a liquid surface of the fuel oil and the height from a bottom surface of the water tank to a water surface of the processed water to be within a predetermined range. Then, the merging section may merge the fuel oil supplied from the fuel oil tank and the processed water supplied from the water tank with a predetermined flow rate ratio.

[0020] In this manner, there are provided the fuel oil tank for storing the fuel oil, the water tank for storing the water, and the in-tank liquid height adjusting device for adjusting the difference between the height from a bottom surface of the fuel oil tank to a liquid surface of the fuel oil and the height from a bottom surface of the water tank to a water surface of the water to be within a predetermined range, thus it becomes possible to merge the fuel oil supplied from the fuel oil tank and the water supplied from the water tank with a desired flow rate ratio by the merging section.

[0021] Specifically, if the relation between the liquid height in the fuel oil tank and the liquid height in the water tank is not adjusted, there is seen such a phenomenon that only one liquid having higher liquid height at that point of time is supplied to the merging section at a place where the fuel oil and the water are merged, while the other liquid is hardly supplied. However, since the present invention is provided with the in-tank liquid height adjusting device, it becomes possible to control a merging ratio between the fuel oil and the water by the merging section.

[0022] In this configuration, the water tank and the fuel tank may be arranged at a position higher than the combustion apparatus, and supply passages of the processed water and the fuel oil from the water tank and the fuel oil tank to the emulsion generation section may be a pump-less passage without having a pump. Then, the fuel oil and the processed water may be supplied to the emulsion generation section by gravity caused by the height difference between the water tank and the fuel oil tank, and the combustion apparatus, and pressure caused by a pump provided in the combustion apparatus.

[0023] In this manner, the supply passages of the processed water and the fuel oil are not provided with a pump, thus a low-cost emulsion fuel supply device having a simple device configuration can be realized. Since a purpose of using an emulsion fuel is cost reduction, realization of a low-cost emulsion fuel supply device also meets the rationale of adopting an emulsion fuel.

[0024] Further, if a pump for supplying the processed water and the fuel is separately installed, it requires a pressure-control valve and a pressure-control system using a computer in order to take a pressure balance between this pump and the pump in the combustion apparatus. However, in the present invention, the supply passages of the processed water and the fuel are not provided with a pump, thus there is no need to separately install a control system for taking a balance between the pumps, and a low-cost emulsion fuel supply device having a simple device configuration can be achieved.

[0025] In the present invention, as raw material water of the emulsion fuel, the processed water in use is produced by removing Ca ions and Mg ions from the raw water and allowing to remain or adding Na ions in the raw water, thus as long as the water tank and the oil tank are arranged at a position higher than the combustion apparatus, supplies of the processed water and the fuel can be performed smoothly and stably without a pump being installed on the supply passages of the processed water and the fuel.

[0026] In this configuration, the emulsion generation section may include a plurality of dispersion parts each having fine hole parts including a through-hole with small diameter and a cylindrical large-diameter part continuously installed downstream of the fine hole parts, the plurality of the dispersion parts being continuously connected to each other in series, and an introduction port for returning surplus fuel discharged from the combustion apparatus to the emulsion generation section, the introduction port being installed on a downstream side of the most upstream fine hole parts.

[0027] With such a configuration, the surplus fuel is prevented from being subjected to an excessive dispersion treatment, and the emulsion fuel supplied to the combustion apparatus can be kept in an incomplete emulsion state, where the emulsion fuel is not completely emulsified.

[0028] The inventors of the present invention have found, as a result of their earnest study, that combustion efficiency is decreased in a combustion apparatus when an emulsion fuel is brought into a complete emulsion state, where an aqueous phase and an oil phase are completely emulsified. Therefore, the present invention has a such configuration that the introduction port for returning the surplus fuel to the emulsion generation section is arranged on the downstream side of the most upstream fine hole parts, thereby preventing conversion of the emulsion fuel supplied to the combustion apparatus into complete emulsion and making it possible to supply the emulsion fuel of excellent combustion efficiency.

[0029] In this configuration, the processed water generation device preferably includes: a soft water generation device for producing soft water from raw water, having an ion exchanger for removing Ca ions, Mg ions, and Fe ions from the raw water and also adding Na ions to the raw water, a tourmaline container for storing tourmaline, and an obsidian container for storing obsidian; a surface tension increasing section for increasing surface tension of the soft water and also increasing a quantity of atomic hydrogen in the soft water, having an introduction pipe for introducing the soft water produced in the soft water generation device and a circulation device for circulating the soft water introduced from the introduction pipe into at least one of the tourmaline container and the obsidian container for 30 minutes or more; and a processed water supply section for supplying processed water having passed through the surface tension increasing section to the water tank.

[0030] In this manner, the surface tension increasing section is provided, thus the emulsion fuel can be produced by using the processed water having high surface tension and the emulsion fuel of high energy efficiency can be supplied.

[0031] In this configuration, an air suction port of the combustion apparatus is preferably connected to a gas supply quantity adjusting section for adjusting a supply quantity of gas to the combustion apparatus within a range of zero to a misfiring air quantity as fuel oil being supplied, beyond which a misfire is caused when a water-free fuel oil is supplied, and an oxygen gas supply section for supplying oxygen gas.

[0032] In this manner, the gas supply quantity adjusting section is provided, thus the combustion apparatus can be efficiently operated. In the step of the processed water generation device of the present invention, atomic hydrogen as an energy source and also oxygen are produced, thus when the processed water supplied from the processed water generation device is used for the emulsion fuel, in principle, a supply of oxygen and the air in the combustion apparatus becomes unnecessary.

[0033] On the other hand, there is provided the oxygen gas supply section, thus even when a ratio of water in the emulsion fuel is increased, a misfire in the combustion apparatus can be suppressed. As a result, it becomes possible to increase a ratio of water in the emulsion fuel, thereby reducing a ratio of the fuel oil, so that operation cost of the combustion apparatus can be reduced.

[0034] In this configuration, the fine hole parts are preferably inclined relative to an extended direction of the emulsion generation section.

[0035] With such a configuration, a fluid is jetted from the fine hole parts to the large-diameter part in an oblique direction and collides against a wall face and the like of the large-diameter part, whereby diffusion of the liquid is further promoted.

[0036] The problems described above can be solved according to an emulsion fuel supply method of the present invention. The method is for supplying an emulsion fuel having an aqueous phase and an oil phase of a fuel oil to a combustion apparatus and includes: a processed water generation step for producing processed water by removing, from raw water, Ca ions and Mg ions contained in the raw water and allowing to remain or adding Na ions in the raw water; a merging step for merging the fuel oil supplied from a tank storing the processed water produced in the processed water generation step and the fuel oil, and the processed water supplied from the tank in a predetermined flow rate ratio; an emulsion generation step for producing the emulsion fuel by supplying a mixture of the fuel oil and the processed water merged in the merging step to an emulsion generation section; and a supply step for supplying the emulsion fuel produced in the emulsion generation step to the combustion apparatus.

[0037] In the merging step of this method, the processed water and the fuel oil may be merged by alternately performing a supply from a water supply pipe having a suction port arranged near a bottom part of the tank and a supply from an oil supply pipe having a suction port attached on a float floating on the surface of a liquid stored in the tank.

[0038] Further, before the merging step, there may be included an in-tank liquid height adjusting step for adjusting the difference between the height from a bottom surface of the water tank storing the processed water supplied after being produced in the processed water generation step to a water surface of the processed water, and the height from a bottom surface of the fuel oil tank storing the fuel oil to a liquid surface of the fuel oil, to be within a predetermined range. Then, in the merging step, the fuel oil supplied from the fuel oil tank and the processed water supplied from the water tank may be merged at a predetermined flow rate ratio.

[0039] In the merging step and the emulsion generation step, the fuel oil and the processed water may be supplied to the emulsion generation section by gravity caused by the height difference between the water tank and the fuel oil tank arranged at a position higher than that of the combustion apparatus, and the combustion apparatus, and pressure caused by a pump provided in the combustion apparatus.

[0040] Further, in the emulsion generation step, a mixture of the fuel oil and the processed water merged in the merging step may be allowed to pass through the emulsion generation section including a plurality of dispersion parts each having fine hole parts including a through-hole with small diameter and a cylindrical large-diameter part continuously installed downstream of the fine hole parts, the plurality of the dispersion parts being continuously connected to each other in series. Also, surplus fuel discharged from the combustion apparatus may be returned to a downstream side of the most upstream dispersion part arranged in the emulsion generation section.

[0041] Further, in the processed water generation step, it is preferred that Mg ions, Ca ions, and Fe ions contained in the raw water are removed from the raw water by ion exchange, and then the raw water is allowed to pass through at least one of the tourmaline container filled with tourmaline and the obsidian container filled with obsidian to produce the processed water.

[0042] Further, in the processed water generation step, it is preferred that Na ion concentration in the processed water is increased more than Na ion concentration in the raw water.

[0043] With such a configuration, it becomes possible to prepare the processed water having high surface tension and high surface activity as a raw material of an emulsion fuel of excellent combustion efficiency.

[0044] Further, since the processed water is removed of Mg ions, Ca ions, and Fe ions and contains Na ions, when the processed water is mixed and stirred with the fuel oil, a fatty acid liberated by hydrolysis of a triglyceride contained in the fuel oil reacts with Na ions, instead of reacting with

Mg ions, Ca ions, and Fe ions, to produce a fatty acid sodium salt serving as a surfactant, thereby making emulsification possible.

[0045] Emulsion produced from the fuel oil and the processed water is derived from the processed water having higher surface tension than the raw water, thus the emulsion has high energy, generates a high heat quantity in combustion, and has excellent combustion efficiency. Specifically, a conventional emulsifier has a property of lowering surface tension of a liquid, which in turn reduces a heat generation quantity of the emulsion fuel in combustion. In contrast, the processed water of the present invention has enhanced surface tension while maintaining a capability of being emulsified with the fuel oil, thus a high heat generation quantity can be achieved.

[0046] In the processed water generation step, surface tension of the processed water measured at a water temperature of 26° C. is preferably adjusted to 50 mN/m or more.

[0047] With such a configuration, the emulsion fuel generating a high heat quantity in combustion can be achieved.

[0048] In the supply step, gas is supplied to the combustion apparatus in a supply quantity within a range of 0 to the misfiring air quantity as fuel oil being supplied, beyond which a misfire is caused when a water-free fuel oil is supplied.

[0049] In this manner, the gas supply quantity adjusting section is provided, thus the combustion apparatus can be efficiently operated. In the step of the processed water generation device of the present invention, atomic hydrogen as an energy source and also oxygen are produced, thus when the processed water supplied from the processed water generation device is used for the emulsion fuel, in principle, a supply of oxygen and the air in the combustion apparatus becomes unnecessary.

Effects of Invention

[0050] According to the present invention, the processed water, produced by removing, from raw water, Ca ions and Mg ions contained in the raw water and allowing to remain or adding Na ions in the raw water, is used as a raw material of the emulsion fuel, thus it becomes possible to produce the emulsion fuel by using the processed water having highly active atomic hydrogen, and supply the emulsion fuel of high energy efficiency.

[0051] Further, using the processed water makes it possible to perform emulsification with the fuel oil without using an emulsifier, thus an emulsifier-free emulsion fuel can be achieved.

[0052] Moreover, the emulsion fuel of the present invention uses the processed water made of soft water from which Ca ions and Mg ions are removed as a raw material, and also does not contain an emulsifier, thus oxidation, rust and corrosion in the combustion apparatus can be suppressed and deterioration of the combustion apparatus caused by the emulsion fuel can be suppressed.

[0053] In this configuration, the tank may be a single tank storing the processed water and the fuel oil, including a water supply pipe having a liquid suction port arranged near a bottom part of the tank and an oil supply pipe having a liquid suction port attached on a float floating on the surface of a liquid stored in the tank, and the merging section may alternately perform a supply of the processed water from the water supply pipe and a supply of the fuel oil from the oil supply pipe to merge the fuel oil and the processed water.

[0054] With such a configuration, it is not necessary to prepare a plurality of tanks for the processed water and the fuel oil, making a device configuration simple. As such, it is not necessary to add a new tank for the processed water to the existing fuel supply device, making it easy to introduce the emulsion fuel supply device of the present invention.

BRIEF DESCRIPTION OF DRAWINGS

[0055] FIG. **1** is a schematic block diagram of an emulsion fuel supply device according to one embodiment of the present invention.

[0056] FIG. **2** is a schematic block diagram of a processed water treatment device according to one embodiment of the present invention.

[0057] FIG. **3** is a schematic longitudinal cross-sectional block diagram of an emulsion generator according to one embodiment of the present invention.

[0058] FIG. **4** is a schematic block diagram of an example of having a separation tank for surplus emulsion in the emulsion fuel supply device according to one embodiment of the present invention.

[0059] FIG. **5** is a schematic block diagram of an emulsion fuel supply device according to a modified example of the present invention.

[0060] FIG. **6** is graphs showing average diameter and standard deviation of emulsion particles in samples, in which heavy oil A is added and stirred in processed water of Example 1, distilled water, and ultrapure water.

[0061] FIG. **7** is a measurement result of surface tension of processed water of Examples 2 to 9 and ultrapure water.

[0062] FIG. **8** is a measurement result of surface tension of processed water of Examples 10 and 11, ultrapure water, raw water, surfactant-added tap water in which a surfactant is added to the raw water.

[0063] FIG. **9** is a measurement result of an ion chromatograph method with the processed water of Example 1 and raw water of the processed water.

DESCRIPTION OF EMBODIMENTS

[0064] Hereinafter, an emulsion fuel supply device and a supply method thereof according to one embodiment of the present invention will be described with reference to the drawings.

[0065] In the present application, an emulsion fuel refers to a fuel in which an aqueous liquid and an oily liquid are dispersed to be converted to a state similar to emulsion, regardless of the presence/absence of an emulsifier. Further, the emulsion fuel includes both complete emulsion in which an aqueous liquid and an oily liquid are emulsified by dispersion and incomplete emulsion in which an aqueous liquid and an oily liquid are mixed to be partially dispersed and partially undispersed.

[0066] As an emulsion fuel of the present embodiment, incomplete emulsion composed of only an aqueous liquid and an oily liquid without using an emulsifier is preferably used.

<Emulsion Fuel Supply Device>

[0067] FIG. **1** is a schematic block diagram of an emulsion fuel supply device **1** according to the present embodiment.

[0068] The emulsion fuel supply device **1** is a device for producing an emulsion fuel from water and a fuel oil and supplying the emulsion fuel and oxygen to a diesel engine **70** as a combustion apparatus. The emulsion fuel supply device **1** includes, as main constitutional elements, a processed water treatment device **10** for producing processed water as a raw material of the emulsion fuel from tap water, a processed water tank **20** for storing the processed water, a fuel oil tank **30** for storing the fuel oil, a liquid feed part **40** for transporting a mixture liquid in which the processed water and the fuel oil are merged to an emulsion generator **50**, an emulsion generator **50** for producing the emulsion fuel from the mixture liquid of the processed water and the fuel oil and also supplying the emulsion fuel to the diesel engine **70**, and a oxygen gas cylinder **60** for mixing the air introduced into the diesel engine **70** with oxygen gas.

[0069] As a combustion apparatus to which the emulsion fuel supply device **1** of the present embodiment is applied, any kinds of internal combustion engines can be applied, so long as they work with heat energy generated by exploding and burning a fuel in a cylinder. For example, the emulsion fuel supply device **1** can be preferably applied to a diesel engine, in particular, a diesel engine for a ship. It can be also applied to a boiler.

[0070] As a fuel oil, a variety of fuel oils may be used. For example, well-known fuel oils used for an emulsion fuel, such as heavy oil A, heavy oil B, heavy oil C, light oil, kerosene, gasoline, and biofuel, can be used.

[0071] The processed water treatment device **10** includes, as shown in FIG. **2**, a soft water generation device **100**, in which a first soft water generator **110**, a second soft water generator **112**, an ion generator **114**, and an obsidian container **116** are connected in series in this order via communication pipes **118***a*, **118***b*, and **118***c*, and a surface tension increasing device **140** connected at a downstream side of the soft water generation device **100**.

[0072] The soft water generation device **100** is a device for producing soft water from raw water.

[0073] The soft water refers to water having a hardness of less than 100 mg/l. The hardness is an index represented by Ca concentration and Mg concentration contained in water and calculated by: hardness=Ca concentration (mg/l)×2.5+ Mg concentration (mg/l)×4.1.

[0074] In the present embodiment, it is preferable to use water having the hardness of less than 100 mg/l, from which Ca ions, Mg ions, and Fe ions are removed.

[0075] Raw water with high pressure such as tap water, for example, is introduced into the first soft water generator **110** from a water supply pipe **120** via a communication pipe **122**.

[0076] Alternatively, as raw water, spring water, well water, rainwater, and water of a river, all subjected to a purification and a disinfection treatments by a known water purifying filter, sterilization apparatus, and the like, as well as clean spring water and well water, may be used and introduced into the first soft water generator **110** by a pump not illustrated via the water supply pipe **120** and the communication pipe **122**.

[0077] An inlet open/close valve **124** functioning as a faucet is provided between the water supply pipe **120** and the communication pipe **122**, and a check valve **126** is provided on the way of the communication pipe **122**. A discharge pipe **128***a* is installed on an outlet side of the obsidian container **116** and an outlet open/close valve **130***a* is provided on the tip or the way of the discharge pipe **128***a*.

[0078] A granular ion exchange resin **132** is filled inside the first soft water generator **110** and the second soft water generator **112**. It is noted that the two soft water generators **110** and **112** can be combined into a single soft water generator.

[0079] The ion exchange resin **132** is for removing metal ions contained in raw water, such as Ca^{2+}, Mg^{2+}, and Fe^{2+}, and converting the raw water into soft water, in particular, for lowering the hardness of the raw water to a level near to zero. As the ion exchange resin **132**, for example, a strongly acidic cation exchange resin ($RzSO_3Na$), in which a styrene-divinyl benzene copolymer having a spherical shape is uniformly sulfonated, is used.

[0080] An ion exchange reaction by the ion exchange resin **132** using $RzSO_3Na$ is as follows.

$$2RzSO_3Na+Ca^{2+}\text{->}(RzSO_3)_2Ca+2Na^+$$

$$2RzSO_3Na+Mg^{2+}\text{->}(RzSO_3)_2Mg+2Na^+$$

$$2RzSO_3Na+Fe^{2+}\text{->}(RzSO_3)_2Fe+2Na^+$$

[0081] In essence, by passing raw water through the ion exchange resin **132**, Ca^{2+}, Mg^{2+}, Fe^{2+}, etc., contained in the raw water are removed and Na is generated.

[0082] On the other hand, by passing the raw water through the ion exchange resin **132**, a hydroxide ion (OH^-) and a hydronium ion (H_3O^+) are generated as follows.

$$H_2O\text{->}H^++OH^-$$

$$H_2O+H^+\text{->}H_3O^+$$

[0083] Thus, when raw water is hard water, the raw water is removed of metal ions such as Ca^{2+}, Mg^{2+}, and Fe^{2+} by passing through the ion exchange resin **132**, and becomes soft water. Further, Na+, OH−, and a hydronium ion (H_3O^+) are generated in the raw water. However, chlorine contained in the tap water passes through the resin as it is without being ionized.

[0084] An ion generator **114** has a plurality of cartridges not illustrated lined up vertically and continuously in the same layout in series, where the each cartridge is filled with a tourmaline powder having an average particle diameter of 5 to 15 □m or a tourmaline pellet having a pellet shape, obtained by mixing a tourmaline powder with other ceramic material and burning a mixture. Alternatively, the cartridge may be filled with a tourmaline powder or a granular tourmaline mixed with a metal plate.

[0085] Tourmaline has a plus electrode and a minus electrode, and because of this plus electrode and minus electrode, water is charged with an electromagnetic wave having a wave length of 4 to 14 □m and a cluster of water is cleaved to produce a hydronium ion (H_3O^+). Energy of the electromagnetic wave having a wave length of 4 to 14 □m is about 0.004 watt/cm^2.

[0086] Water is converted to soft water of a nearly zero hardness by passing through the ion exchange resin **132** and tourmaline is rubbed against each other in this soft water. In the soft water of a nearly zero hardness, adhesion of Mg ion and Ca ion to the minus electrode of tourmaline can be prevented, thus deterioration of a function of tourmaline as a plus electrode and a minus electrode can be prevented.

[0087] As the metal plate, at least one kind of metal selected from aluminum, stainless steel, and silver is used. It is preferred that metal used for this purpose does not become rusty in water or dissolve in water. Aluminum has a bleaching effect as well as a bactericidal effect and an antimicrobial effect, stainless steel has a cleaning-improving effect as well as a bactericidal effect and an antimicrobial effect, and silver has a bactericidal effect and an antimicrobial effect.

[0088] A weight ratio of tourmaline to the metal plate is preferably from 10:1 to 1:10. When the weight ratio exceeds this range, one material occupies too much ratio and effects of the both materials cannot be exerted simultaneously.

[0089] Each of the cartridges of the ion generator **114** is configured such that water passing through a number of holes formed on a bottom surface of the cartridge is jetted upward from below into a tourmaline powder or a tourmaline pellet. In this process, since tap water has high water pressure, the size and the number of the holes are set in such a way that the water having high water pressure vigorously collides with a tourmaline powder or a tourmaline pellet inside the cartridge and the tourmaline powder or the tourmaline pellet is stirred in the cartridge by force of the water. A purpose for jetting water to tourmaline for stirring tourmaline is that, by generating friction between tourmaline and water by the stirring, the plus and minus electrodes are dissolved from tourmaline into the water and cleave clusters of water, so that a large quantity of hydronium ions (H_3O^+) are produced.

[0090] The plus and minus electrodes are generated when tourmaline is rubbed against each other and, by the contact of the electrodes with water, minus ions are increased in the water. It is noted that when a large quantity of hydronium ions (H_3O^+) are desired to be produced by cleaving clusters of water, the cartridge may be filled with only tourmaline.

[0091] Since tourmaline contains the plus and minus electrodes, when tourmaline is stirred in water, water is dissociated into a hydrogen ion and a hydroxide ion.

$$H_2O\text{->}H^++OH^-$$

[0092] Further, a hydronium ion (H_3O^+) having a surfactant effect is produced by a hydrogen ion and water. An amount of the hydronium ion produced in the ion generator **114** is much higher than that generated in the ion exchange resin **132**.

$$H_2O+H^+\text{->}H_3O^+$$

[0093] A part of the produced hydronium ions are combined with water to produce hydroxyl ions ($H_3O_2^-$) and hydrogen ions.

$$H_3O^++H_2O\text{->}H_3O_2^-+2H^+$$

[0094] The water passing through the ion exchange resin **132** is allowed to pass through the ion generator **114** to generate a hydronium ion (H_3O+), a hydroxyl ion ($H_3O_2^-$), H^+, and OH^-. It is noted that chlorine passing through the ion exchange resin **132** and Na produced in the ion exchange resin **132** pass through the ion generator **114** as they are.

[0095] Next, the water passing through the ion generator **114** is allowed to pass through the inside of the obsidian container **116** storing obsidian having a particle diameter of about 5 mm to 50 mm There is no limitation on a production area of obsidian.

[0096] When the water passing through the ion generator **114** is allowed to pass through the obsidian container **116**, the water is added with e^- (negative electron). As a result, chlorine contained in the tap water becomes chloride ions by the negative electrons.

$$Cl_2+2e^-\text{->}2Cl^-$$

[0097] This Cl^- and the above Na^+ are brought into a stable state as an ion. A stable state refers to a state where an ion condition is maintained over a long period of time. Further, the hydroxyl ion is also brought into a stable state as an ion. By allowing water to pass through obsidian, hydronium ions are further produced, and hydroxyl ions and hydrogen ions are also further produced as compared with water passing through the ion generator **114**.

$$H_2O+H^+\text{->}H_3O^+$$

$$H_3O^++H_2O\text{->}H_3O_2^-+2H^+$$

[0098] Besides those, the following reactions also occur when water is passing through obsidian.

$$OH^-+H^+\text{->}H_2O$$

$$2H++2e^-\text{->}2H_2$$

[0099] Further, when water is passing through the obsidian container **116**, an oxidation-reduction potential of the water is shifted from +340 mV to −20 to −240 mV due to minus electrons of obsidian. Further the water passing through obsidian contains a large quantity of dissolved oxygen and active hydrogen.

[0100] The soft water generation device **100** of the present embodiment includes the first soft water generator **110**, the second soft water generator **112**, the ion generator **114**, and the obsidian container **116**, however the present invention is not limited thereto and the device may be any of devices capable of removing Ca ions, Mg ions, and Fe ions from raw water.

[0101] Further, the order of passing water through the ion generator **114** and the obsidian container **116** may be reversed, and the water may be allowed to pass through the obsidian container **116** first, and then pass through the ion generator **114**.

[0102] A downstream side of the soft water generation device **100** is connected to the surface tension increasing device **140** by connecting the a communication pipe **118*d*** to an outlet open/close valve **130*a*** on the discharge pipe **128*a*** of the soft water generation device **100**.

[0103] The surface tension increasing device **140** is a device for increasing surface tension of the soft water and also increasing a quantity of atomic hydrogen in the soft water by passing the soft water produced from the raw water in the soft water generation device **100** through a tourmaline powder or a tourmaline pellet, and/or the obsidian container **116**.

[0104] The surface tension increasing device **140** of the present embodiment is, as shown in FIG. **2**, formed by connecting the obsidian containers **116** in series, however, the device is not limited thereto, and it may be formed by connecting a plurality of the ion generators **114** in series or by connecting the ion generators **114** and the obsidian containers **116** in series.

[0105] Configurations of the ion generator **114** and/or the obsidian container **116**, constituting the surface tension increasing device **140**, are the same as those included in the soft water generation device **100**.

[0106] A discharge pipe **128*b*** is installed on an outlet side of the most downstream obsidian container **116** and an outlet open/close valve **130*b*** is provided on the tip or the way of the discharge pipe **128*b***. The open/close valve **130*b*** is connected to an introduction pipe **21** for supplying the processed water produced in the surface tension increasing device **140** to the processed water tank **20** shown in FIG. **1**.

[0107] Processed water is produced from raw water by passing the raw water through the soft water generation device **100** and then the surface tension increasing device **140**.

[0108] The processed water contains large quantities of Na^+, Cl^-, H^+, OH^-, H_2, hydronium ions (H_3O^+), hydroxyl ions ($H_3O_2^-$), active hydrogen (atomic hydrogen), and dissolved oxygen.

[0109] However, soft water produced by passing the raw water through the soft water generation device **100**, but not the surface tension increasing device **140**, may be also used as processed water.

[0110] The process water passing through the soft water generation device **100** and then the surface tension increasing device **140** contains a more quantity of active atomic hydrogen having high energy, and has higher energy, as compared to the one passing through the soft water generation device **100**, but not the surface tension increasing device **140**. That is, the former produces more energy during combustion.

[0111] A hydroxyl ion ($H_3O_2^-$), which is found in large quantities in the processed water passing through the soft water generation device **100** and then the surface tension increasing device **140**, undergoes, during combustion, a chemical change in which two O contained in the ion are converted to O_2, while three H are converted to active atomic hydrogen that is burnt after becoming H gas.

[0112] After raw water (tap water) is softened by the soft water generation device **100**, the raw water is subjected to repeating a treatment of passing through at least one of tourmaline and obsidian for 30 minutes or more up to several hours using the surface tension increasing device **140** to obtain the processed water of the present embodiment. The processed water thus obtained contains Mg ions, Ca ions, and Fe ions in an amount equal to or less than the detection lower limit of an ion chromatograph method, while concentration of Na ions is increased 3 times or more, preferably 3.5 times or more, than the raw water.

[0113] Further, surface tension of the processed water is higher than that of the raw water (tap water) and increased to the same level as that of ultrapure water.

[0114] In this manner, the processed water treated with the processed water treatment device **10** of the present embodiment does not contain Mg ions, Ca ions, or Fe ions, and has high concentration of Na ions, thus when the processed water is mixed and stirred with an oil, a fatty acid is liberated by hydrolysis of a triglyceride contained in the oil, and reacts with Na ions to produce a fatty acid sodium salt as a surfactant. Therefore, the processed water of the present embodiment can be emulsified by being mixed and stirred with a fuel oil without using an emulsifier.

[0115] Thus, incomplete emulsion obtained by emulsifying the processed water of the present embodiment and the fuel oil can be used as an emulsion fuel.

[0116] The emulsion fuel of the present embodiment is an emulsifier-free emulsion fuel, which is produced by emulsifying the processed water of the present embodiment and the fuel oil. Since surface tension of the emulsion fuel increases through the surface tension increasing device **140** and the processed water used for producing the emulsion fuel contains atomic hydrogen, the emulsion fuel generates a higher heat quantity in combustion and exhibits better combustion efficiency than the fuel oil used as a raw material.

[0117] The processed water tank **20** is a tank for storing the processed water produced by the processed water treatment device **10** and includes an introduction pipe **21** for introducing the processed water from the processed water treatment device **10** to the processed water tank **20**, a water supply pipe **22** for supplying the processed water in the processed water tank **20** to a liquid feed part **40**, and a ball tap **23** for keeping a height of the processed water in the processed water tank **20** at a predetermined water level.

[0118] The ball tap **23** is a known ball tap, having a floating ball fixed to a tip of a support shaft that is attached to a valve on the introduction pipe **21**. The ball tap **23** is configured that the floating ball floating on a liquid surface moves up and down in accompany with an up-and-down movement of the liquid surface, and when a location of the floating ball becomes lower than a predetermined position, the valve on the introduction pipe **21** is opened to supply water into the processed water tank **20** from the introduction pipe **21**.

[0119] The water supply pipe **22** is provided with an electromagnetic valve **25** operable from an operation panel not illustrated, a flow rate control valve **27** for controlling a flow rate of the processed water from the water supply pipe **22**, and a flow rate sensor **28**.

[0120] The fuel oil tank **30** is a tank for storing a fuel oil supplied from a crude oil tank **34** and includes an introduction pipe **31** for introducing a fuel oil from the crude oil tank **34** to the fuel oil tank **30**, an oil supply pipe **32** for supplying the fuel oil in the fuel oil tank **30** to the liquid feed part **40**, and a ball tap **33** for keeping a height of the fuel oil in the fuel oil tank **30** at a predetermined liquid level.

[0121] The configuration of the ball tap **33** is the same as the ball tap **23**, and with the ball taps **23** and **33**, liquid heights of the processed water tank **20** and the fuel oil tank **30** are kept at the same height with each other.

[0122] The oil supply pipe **32** is provided with a filer **36** for removing dirt and the like in the fuel oil, a flow rate control valve **37** for controlling a flow rate of the fuel oil from the oil supply pipe **32**, and a flow rate sensor **38**.

[0123] The processed water tank **20** and the fuel oil tank **30** are arranged at a position higher than the diesel engine **70**. With such a configuration, the processed water and the fuel oil can be supplied to the diesel engine **70** via the liquid feed part **40** and the emulsion generator **50** only by gravity of the processed water tank **20** and the fuel oil tank **30**, and pressure of a pump **76** originally installed in the diesel engine **70**, thus there is no need of providing a separate pump with the liquid feed part **40**.

[0124] The liquid feed part **40** is a part for merging the processed water from the water supply pipe **22** and the fuel oil from the oil supply pipe **32** into a single liquid feed pipe **41** and feeding a merged liquid to the emulsion generator **50**. An upstream side of the liquid feed part **40** is connected to the water supply pipe **22** and the oil supply pipe **32**, while a downstream side of the liquid feed part **40** is provided with the liquid feed pipe **41** connected to the emulsion generator **50**, a filter **42** for removing a dirt and the like of a liquid passing through the liquid feed pipe **41**, and a scale **43** displaying scales in units of 1 cm and 1 mm, arranged along the liquid feed pipe **41**.

[0125] The liquid feed pipe **41** is made of a transparent tube, so that a liquid flowing inside of the pipe can be visually inspected from the outside. In the liquid feed pipe **41**, the processed water and the fuel oil are separated and flow in a strip pattern where the processed water and the fuel oil are alternately arranged. Thus, a mixing ratio of the processed water and the fuel oil can be known by reading lengths of a processed water part and a fuel oil part from the scales displayed on the scale **43**. The mixing ratio may be read by visual inspection for calculation or taken as an image by a digital camera and analyzed by a computer for calculation.

[0126] The liquid feed pipe **41** is arranged in such a manner that its axial direction becomes horizontal over the whole length.

[0127] Having such a configuration can prevent a misfire from easily occurring in the diesel engine **70** when supplies of the processed water and the fuel oil to the diesel engine **70** are stopped and then restarted.

[0128] Specifically, the processed water is heavier in specific gravity than the fuel oil, thus, if the liquid feed pipe **41** has a portion where the axial direction of the liquid feed pipe **41** is tilted with respect to the horizontal direction, the processed water ends up being shifted to a lower side and the fuel oil ends up being shifted to a higher side when supplies of the processed water and the fuel oil to the diesel engine **70** are stopped. When the supplies to the diesel engine **70** are restarted, the processed water part accumulated in the lower side reaches the diesel engine **70** via the emulsion generator **50** and causes temporal reduction in a ratio of the fuel oil in the emulsion fuel, thus there is a danger of a misfire in the diesel engine **70**.

[0129] Further, when the liquid feed pipe **41** is arranged with its axial direction set horizontal over the whole length, a ratio of the processed water to the fuel oil hardly changes in various parts inside the liquid feed pipe **41** during stopping of the supplies of the processed water and the fuel oil, thus there is no need to do a work such as removing the processed water from the liquid feed pipe **41** before restarting the supplies in order to prevent a misfire in the diesel engine **70**, and workability is improved.

[0130] The total length of the liquid feed pipe **41** is 50 cm or less, preferably 30 cm or less, and further preferably 20 cm or less. By keeping the total length of the liquid feed pipe **41** in such a short range as this, the ratio of the processed water to the fuel oil can be prevented from changing while the processed water and the fuel oil flow in the liquid feed pipe **41** or during an interval between the stop and the restart of the supplies to the diesel engine **70**.

[0131] The emulsion generator **50** is a device for jetting a mixture of the processed water and the fuel oil, fed from the liquid feed part **40**, from fine holes to a larger diameter space for emulsification.

[0132] The emulsion generator **50** is, as shown in FIG. **3**, shaped in an approximately cylindrical lengthy body in which housings **51**, **54**, and **57** are connected in series.

[0133] The housing **51** is formed in approximately cylinder shape. A cylindrical connection part **51***a* for connecting to the liquid feed pipe **41** is formed at an axial end of the housing **51** on an upstream side. A closing part **53** for closing an end part and a pair of fine holes **53***a* including through holes obliquely penetrating the closing part **53** with respect to an axial direction are formed at an axial end of the housing **51** on a downstream side.

[0134] The pair of the fine holes **53***a* are adjacently formed in a width direction perpendicular to the axial direction of the housing **51** and also obliquely formed so as to mutually approach to each other toward a downstream side. In this manner, since the pair of the fine holes **53***a* are obliquely formed so as to mutually approach to each other toward the downstream side, two flows of liquid proceeding the fine holes **53***a* are jetted into a large-diameter space **55** and collide with each other, thus diffusion of the liquid is further promoted.

[0135] The pair of the fine holes **53***a* are formed to be symmetrical to each other with a plane passing through a central axis of the housing **51** as a center.

[0136] It is noted that the number of the fine holes **53***a* is not limited to a pair and a plurality of three or more, for example four, fine holes may be installed.

[0137] A large-diameter space **52** in a large diametric cylindrical shape, having a larger diameter than the fine holes **53***a*, is formed between the connection part **51***a* and the closing part **53**.

[0138] The housing **54** has the same shape as the housing **51**, except that a connection part **54***a* is formed connectably with an outer periphery of the closing part **53**.

[0139] The housing **57** has the same shape as the housing **54**, except that a return emulsion introduction port **59** as an introduction port for introducing surplus emulsion fuel that is surplus fuel returning from the diesel engine **70** is provided on a side surface of a large-diameter space **58** on a downstream side of the fine holes **53***a* and **56***a*, and a connection part **58***b* connected to a supply pipe **71** for supplying the emulsion fuel to the diesel engine **70** is provided at an axial end part of the housing **57** on a downstream side.

[0140] In the emulsion generator **50**, a mixture of the processed water and the fuel oil is supplied to the large-diameter space **52** from the connection part **51***a* by the pump **76** equipped in the diesel engine **70** and connected to the supply pipe **71**, and jetted into the large-diameter space **55** through the fine holes **53***a*. Emulsification is performed by jetting the mixture into the large-diameter space **55** from the fine holes **53***a* and diffusing the mixture. Further, when the mixture is jetted into the large-diameter space **58** from the fine holes **56***a*, the similar diffusion occurs and emulsification is promoted again. Then, the mixture is merged with surplus emulsion fuel that is returned from a surplus emulsion discharge pipe **72** of the diesel engine **70** through the return emulsion introduction port **59**, and supplied to the diesel engine **70** through the connection part **58***b* and the supply pipe **71**.

[0141] It is noted that, in the present embodiment, it is configured that the surplus emulsion fuel returning from the diesel engine **70** is returned to the emulsion generator **50** through the surplus emulsion discharge pipe **72**, however, as shown in FIG. **4**, the surplus emulsion discharge pipe **72** may be connected to a separation tank **80** for separating the surplus emulsion into the processed water and the fuel oil.

[0142] The separation tank **80** is a tank for storing the surplus emulsion fuel supplied from the surplus emulsion discharge pipe **72** and separating the surplus emulsion into the processed water and the fuel oil by a still-standing treatment. A downstream end part of the surplus emulsion discharge pipe **72** is arranged to be positioned on a liquid surface of the separation tank **80**.

[0143] An upstream end part of the water supply pipe **82** is connected to a bottom surface of the separation tank **80** in a manner that an opening of the water supply pipe **82** serving as a suction port is positioned near the bottom part of the separation tank **80**.

[0144] When the processed water and the fuel oil are stored in the separation tank **80**, the processed water having greater specific gravity is stored near the bottom surface of the tank to form a water phase W, and the fuel oil having smaller specific gravity is stored near the liquid surface of the tank to form an oil phase O, thus creating a two-phase state where the water phase W and the oil phase O are separated. Consequently, it becomes possible to discharge the processed water stored near the bottom surface of the separation tank **80** from the opening at the upstream end part of the water supply pipe **82**.

[0145] An upstream part of an oil supply pipe **83** is arranged on an upper part of the separation tank **80**, and a suction port at an upstream end part of the oil supply pipe **83** is, as shown in FIG. **4**, fixed to a float **81** that is made of a known material. An opening serving as the upstream suction port of the oil supply pipe **83**, fixed to the float **81**, is positioned inside the oil phase O and makes it possible to discharge the fuel oil stored near the liquid surface of the separation tank **80**.

[0146] The water supply pipe **82** and the oil supply pipe **83** are each provided with an electromagnetic valve.

[0147] When the surplus emulsion fuel is returned to the large-diameter space **58** via the surplus emulsion discharge pipe **72** and the return emulsion introduction port **59**, the viscosity of the emulsion fuel introduced into the diesel engine **70** from the large-diameter space **58** is increased, which in turn increases the load to the diesel engine **70**, thus the temperature of the diesel engine **70** may be increased. However, as shown in FIG. **4**, when a configuration is made such that the surplus emulsion fuel is separated in the separation tank **80** and the separated processed water and fuel oil are returned to the processed water tank **20** and the fuel oil tank **30**, respectively, the surplus emulsion fuel is mixed with the processed water and the fuel oil after separation, thus the temperature rise of the diesel engine **70** due to the load increase can be suppressed.

[0148] It is noted that, in the example shown in FIG. **4**, the processed water and the fuel oil separated in the separation tank **80** are returned to the processed water tank **20** and the fuel oil tank **30**, respectively, however, the separated processed water may be discarded instead of returning to the processed water tank **20**.

[0149] The emulsion fuel produced in the emulsion generator **50** is made of incomplete emulsion, which is not in a completely emulsified state.

[0150] The diesel engine **70** is a known diesel engine for a ship and includes a pump **76** for feeding the emulsion fuel supplied from a supply pipe **71** to the diesel engine **70**, a surplus emulsion discharge pipe **72** for discharging surplus emulsion fuel in the diesel engine **70**, an air suction port **73** for introducing the air via a filter **79** from the open air outside an engine compartment not illustrated, where the diesel engine **70** is installed, and an exhaust port **74** for exhausting an exhaust gas.

[0151] The air suction port **73** is provided with a valve **78** for adjusting an introduction quantity of the air from zero to a desired quantity. Further, an oxygen gas cylinder **60** is connected to the air suction port **73** via an oxygen introduction pipe **61**. Thus, the air suction port **73** is configured such that the air introduced into the diesel engine **70** can be mixed with oxygen gas by controlling an electromagnetic valve **62** installed on the oxygen introduction pipe **61** from an operation panel not illustrated on the basis of a measured value of a flow rate measuring instrument **63** installed on the oxygen introduction pipe **61**.

<Emulsion Fuel Supply Method>

[0152] The emulsion fuel of the present embodiment is produced by the following emulsion fuel supply method and supplied to the diesel engine **70**.

[0153] First, a raw water processing step is performed to prepare processed water from raw water. However, the emulsion fuel supply method does not need to include the raw water processing step and processed water prepared in advance may be used.

[0154] In the raw water processing step, pressurized raw water such as tap water is supplied to the processed water treatment device **10** shown in FIG. **2**.

[0155] By passing the raw water through the ion exchange resin **132** made of a strongly acidic cation exchange resin and the like in the first soft water generator **110** and the second soft water generator **112**, the raw water is removed of metal ions contained in the raw water, such as Ca^{2+}, Mg^{2+}, and Fe^{2+}, and converted into soft water, and, in the same time, Na^{+}, OH^{-}, and a hydronium ion (H_3O^{+}) are produced in the raw water.

[0156] Next, the water passing through the first soft water generator **110** and the second soft water generator **112** is supplied to the ion generator **114** and allowed to pass through a tourmaline powder having an average particle diameter of 5 to 15 □m or a tourmaline pellet obtained by mixing a tourmaline powder with other ceramic material and then burning a mixture. By this treatment, water is charged with an electromagnetic wave having a wave length of 4 to 14 □m and a cluster of water is cleaved to generate a hydronium ion (H_3O^{+}), a hydroxyl ions ($H_3O_2^{-}$), H^{+}, and OH^{-}.

[0157] The water is allowed to pass through the inside of the obsidian container **116** storing obsidian having a particle diameter of about 5 mm to 50 mm Hydronium ions are further generated, and also hydroxyl ions and hydrogen ions are further generated in the water passing through obsidian as compared with the water passing through the ion generator **114**. Soft water is produced by the above treatment.

[0158] Subsequently, the soft water is allowed to pass through at least one of the ion generator **114** and the obsidian container **116** to produce processed water. Specifically, a circulation time in the ion generator **114** only, in the obsidian container **116** only, or in both the ion generator **114** and the obsidian container **116** is set to be 30 minutes or more.

[0159] Subsequently, the processed water is supplied to the processed water tank **20** from the introduction pipe **21**. Further, a fuel oil is supplied to the fuel oil tank **30** from the crude oil tank **34** through the introduction pipe **31**. During this process, liquid heights of the processed water tank **20** and the fuel oil tank **30**, i.e., quantities of the water and the oil, are kept at a predetermined height by the ball taps **23** and **33**, respectively.

[0160] The liquid heights of the processed water tank **20** and the fuel oil tank **30** are adjusted to have substantially the same heights, specifically the liquid height difference between them is 3 cm or less and preferably 1 cm or less.

Having such a configuration makes it possible to feed the processed water and the fuel oil to the liquid feed part **40** at a proper ratio.

[0161] When the liquid heights of the processed water tank **20** and the fuel oil tank **30** are not controlled, a ratio of the processed water to the fuel oil fed to the liquid feed pipe **41** varies depending on which is higher between the liquid height of the processed water tank **20** and the liquid height of the fuel oil tank **30**, thus this configuration is not desirable. For example, at a timing at which the liquid height of the processed water tank **20** is higher than that of the fuel oil tank **30**, only the processed water is fed to the liquid feed pipe **41**, and interfacial tension between the processed water and the fuel oil prevents the fuel oil from entering the liquid feed pipe **41**. Conversely, at a timing at which the liquid height of the fuel oil tank **30** is higher than that of the processed water tank **20**, only the fuel oil is fed to the liquid feed pipe **41**, and interfacial tension between the processed water and the fuel oil prevents the processed water from entering the liquid feed pipe **41**.

[0162] Next, the pump **76** of the diesel engine **70** is driven while the electromagnetic valve **25** is closed, so that only the fuel oil is fed to the liquid feed pipe **41** from the fuel oil tank **30** by pressure of the pump **76**.

[0163] When the fuel oil reaches the diesel engine **70**, the diesel engine **70** is ignited to perform combustion of the fuel oil.

[0164] Then, the electromagnetic valve **25** is opened to mix the processed water with the fuel oil passing through the liquid feed pipe **41**, thereby supplying the fuel oil and the processed water. In the liquid feed pipe **41**, a phase of the processed water and a phase of the fuel oil are alternately proceeding.

[0165] A ratio between the processed water and the fuel oil circulating the liquid feed pipe **41** can be calculated by measuring the length of the phase of the processed water and the length of the phase of the fuel oil with the scale **43**. The ratio between the processed water and the fuel oil is adjusted by the flow rate control valves **27** and **37**.

[0166] The ratio between the processed water and the fuel oil is from 2:8 to 5:5, preferably from 2.5:7.5 to 5:5. When the ratio of the processed water exceeds 40%, a misfire easily occurs in the diesel engine **70**, however a misfire rarely occurs even when the ratio of the processed water becomes 35 to 50% if oxygen gas is mixed into the air suction port **73** from an oxygen introduction pipe by opening an electromagnetic valve **62** of the oxygen gas cylinder **60**.

[0167] A mixture of the processed water and the fuel oil passing through the liquid feed pipe **41** is fed to the emulsion generator **50** by gravity of the processed water tank **20** and the fuel oil tank **30** and pressure of the pump **76**, and jetted into the large-diameter spaces **55** and **58** from the fine holes **53***a* and **56***a*, whereby the emulsion fuel in which the processed water and the fuel oil are incompletely emulsified is produced.

[0168] When the emulsion fuel reaches the diesel engine **70**, to which only the fuel oil has been supplied, the emulsion fuel replaces the fuel oil and is used for combustion in the diesel engine **70**.

[0169] A frequency of the diesel engine **70** supplied with the emulsion fuel having a ratio of 3:7 between the processed water and the fuel oil is comparable or superior to that of the diesel engine **70** supplied with the 100% fuel oil without being mixed with the processed water. A comparable or more amount of energy can be obtained even when the processed water is dispersed.

[0170] It is noted that, in the present embodiment, the ratio between the processed water and the fuel oil fed to the liquid feed pipe **41** is adjusted by controlling the flow rate control valves **27** and **37**, however the present invention is not limited thereto, and the processed water and the fuel oil may be alternately supplied to the liquid feed pipe **41** by controlling the electromagnetic valve **25** installed on the water supply pipe **22** and an electromagnetic valve not illustrated, installed on the oil supply pipe **32**, from an operation panel not illustrated.

[0171] Specifically, the electromagnetic valve of the fuel oil, not illustrated, is set to open when the electromagnetic valve **25** of the processed water is closed, and conversely, the electromagnetic valve **25** of the processed water is set to open when the electromagnetic valve of the fuel oil, not illustrated, is closed. With such a configuration, the ratio of the processed water and the fuel oil fed to the liquid feed pipe **41** is adjusted by controlling a ratio of the number of seconds specified as an opening time of the electromagnetic valve **25** of the processed water and the electromagnetic valve of the fuel oil, not illustrated.

[0172] Practically, in addition to the configuration of the emulsion fuel supply device **1** shown in FIG. **1**, the electromagnetic valve not illustrated is installed on the oil supply pipe **32**, and also the operation panel not illustrated for controlling the above electromagnetic valve not illustrated and the electromagnetic valve **25** is installed.

[0173] The operation panel is provided with a setting screen for setting a supply timing of the electromagnetic valve not illustrated and the electromagnetic valve **25**. Further, the operation panel including a CPU, a storage section, and a timer, is connected to a control device, not illustrated, that is in turn connected to the electromagnetic valve not illustrated and the electromagnetic valve **25**. This configuration makes it possible to control the electromagnetic valve not illustrated and the electromagnetic valve **25** by the CPU based on a control program stored in the storage section.

[0174] Further, when the emulsion fuel is supplied to the diesel engine **70**, the air is supplied from the air suction port **73**. An air quantity in this operation is set within a range of zero in the air quantity, i.e., no air is supplied, to the air quantity, beyond which a misfire is caused to the diesel engine **70** due to incomplete combustion when supplied with a water-free fuel oil (hereinafter, referred to as a "misfiring air quantity as fuel oil being supplied").

[0175] The supply quantity of the air is adjusted by controlling a valve not illustrated while viewing an air quantity display, not illustrated, installed on the air suction port **73**.

[0176] When a water-free fuel oil is supplied to the diesel engine **70**, a misfire occurs in the diesel engine **70** if the supply air quantity from the air suction port **73** becomes less than the misfiring air quantity as fuel oil being supplied. However, when the emulsion fuel of the present embodiment is supplied, a misfire does not occur in the diesel engine **70** even if the supply air quantity from the air suction port **73** is less than the misfiring air quantity as fuel oil being supplied. This is because the emulsion fuel of the present embodiment has higher energy than the fuel oil. Furthermore, a misfire does not occur in the diesel engine **70** with the supply air quantity in which no air is supplied from the air suction port **73**, thus, the emulsion fuel of the present embodiment does not require a supply of the air, oxygen, or the like for operating the diesel engine **70**.

[0177] Further, when the emulsion fuel of the present embodiment is supplied, a gas supplied from the air suction port **73** may be any of the air, the air mixed with oxygen, and oxygen.

[0178] Further, in the present embodiment, the diesel engine **70** is efficiently operated when the supply quantity of the air from the air suction port **73** is set to zero and the supply of the air is cut off. Since the processed water of the present embodiment contains oxygen as well as atomic hydrogen as energy source, supplies of oxygen and the air to the diesel engine **70** become, in principle, unnecessary.

[0179] When the valve-opening time of the electromagnetic valve of the fuel oil, which is not illustrated, is set to "n1 sec." and the valve-opening time of the electromagnetic valve **25** of the processed water is set to "n2 sec." on a setting screen of the operation panel, a control process by the control device is performed as follows. For example, n1 sec. and n2 sec. are set to 3 to 4 seconds and 1 to 2 seconds, respectively. When a start button is pressed on the setting screen of the operation panel under a state that the pump **76** of the diesel engine **70** is driven, the control process is started. The control process is executed by the CPU of the control device.

[0180] First, it is determined whether the timer reaches n1 seconds after being reset to zero. If the timer does not reach n1 seconds, it is determined again whether the timer reaches n1 seconds.

[0181] If the timer reaches n1 seconds, the electromagnetic valve on the oil supply pipe **32** is closed, the electromagnetic valve **25** is opened, and then the timer is reset to zero.

[0182] Next, it is determined whether the timer reaches n2 seconds. If the timer does not reach n2 seconds, it is determined again whether the timer reaches n2 seconds.

[0183] If the timer reaches n2 seconds, the electromagnetic valve **25** on the water supply pipe **22** is closed and the electromagnetic valve on the oil supply pipe **32** is opened.

[0184] Then, it is determined whether a stop button is pressed on the setting screen of the operation panel. If the stop button is not pressed, the first step is repeated.

[0185] If the stop button is pressed, the electromagnetic valve on the water supply pipe **22** is closed, thereby completing the process.

[0186] By the above process, the processed water and the fuel oil are alternately fed to the liquid feed pipe **41** from the water supply pipe **22** and the oil supply pipe **32** for the seconds set on the setting screen, and then the emulsion fuel in which the processed water and the fuel oil are dispersed at a desired ratio is passed through the emulsion generator **50** and lightly emulsified by stirring. Thereby the emulsion fuel can be ready to be supplied to the diesel engine **70**.

Modified Examples

[0187] In the present embodiment, the processed water tank **20** for storing the processed water and the fuel oil tank **30** for storing the fuel oil are provided separately and independently. However, as shown in FIG. **5**, the processed water and the fuel oil may be stored in a single water/oil tank **20'**.

[0188] FIG. **5** shows an emulsion fuel supply device **1'** according to a modified example, including the single water/oil tank **20'** for storing the processed water and the fuel oil.

[0189] The emulsion fuel supply device **1'** of the present example has the same configuration with the emulsion fuel supply device **1** shown in FIG. **1**, except that: the water/oil tank **20'** is provided in place of the processed water tank **20** and the fuel oil tank **30** shown in FIG. **1**; the ball taps **23** and **33** for adjusting liquid quantities are not provided at the tips of the introduction pipes **21** and **31** from the processed water treatment device **10** and the crude oil tank **34** shown in FIG. **1**; an upstream tip of an oil supply pipe **32'** for supplying the fuel oil to an liquid feed pipe **41'** is attached to a float **33'**; and the surplus emulsion discharge pipe **72** is branched into a discharge pipe **72*a*** connected to the return emulsion introduction port **59** and a discharge pipe **72*b*** connected the water/oil tank **20'**.

[0190] The water/oil tank **20'** is a tank for storing the processed water supplied from the processed water treatment device **10** via the introduction pipe **21** and the fuel oil supplied from the crude oil tank **34** via the introduction pipe **31**. The tank has a mixer-less structure having no stirring device for stirring a mixture of the processed water and the fuel oil. The emulsion generator **50** located downstream of the tank is equipped with capability to emulsify the processed water and the fuel oil that are completely separated from each other, thus it is not necessary to install a stirring device in the water/oil tank **20'**. The water/oil tank **20'** being a mixer-less tank can simplify a configuration of the device.

[0191] In the case such that quantities of the processed water and the fuel oil are reduced in the water/oil tank **20'**, the processed water and the fuel oil are supplied by opening valves **21*a*** and **31*a*** by an operator.

[0192] An upstream end part of a water supply pipe **22'** is connected on a bottom surface of the water/oil tank **20'** in such a way that an opening of the pipe as a suction port is positioned near the bottom part of the water/oil tank **20'**.

[0193] When the processed water and the fuel oil are stored in the water/oil tank **20'**, the processed water having greater specific gravity is stored near the bottom surface of the tank to form a water phase W, and the fuel oil having smaller specific gravity is stored near the liquid surface of the tank to form an oil phase O, thus creating a two-phase state where the water phase W and the oil phase O are separated. Consequently, it becomes possible to discharge the processed water stored near the bottom surface of the water/oil tank **20'** from the opening of the upstream end part of the water supply pipe **22'**.

[0194] An upstream part of an oil supply pipe **32'** is arranged on an upper part of the water/oil tank **20'**, and a suction port at the upstream end part of the oil supply pipe **32'** is, as shown in FIG. **5**, fixed to a float **33'** that is made of a known material. An opening serving as the upstream suction port of the oil supply pipe **32'**, fixed to the float **33'**, is positioned inside the oil phase O, and makes it possible to discharge the fuel oil stored near the liquid surface of the water/oil tank **20'**.

[0195] The water supply pipe **22'** and the oil supply pipe **32'** are provided with electromagnetic valves **25'** and **35'**, respectively, and the electromagnetic valves **25'** and **35'** are connected to an operation panel not illustrated, configured such that alternate supplies of the processed water and the fuel oil can be controlled from the operation panel.

[0196] Specifically, the electromagnetic valve **35'** of the fuel oil is set to open when the electromagnetic valve **25'** of the processed water is closed, and conversely, the electromagnetic valve **25'** of the processed water is set to open when the electromagnetic valve **35'** of the fuel oil is closed. With such a configuration, a ratio of a processed water quantity and a fuel oil quantity fed to the liquid feed pipe **41'** is adjusted by controlling a ratio of the number of seconds specified as an opening time of the electromagnetic valve **25'** of the processed water and the electromagnetic valve **35'** of the fuel oil.

[0197] Further, the surplus emulsion discharge pipe **72** is branched into the discharge pipe **72***a* connected to the return emulsion introduction port **59** and a discharge pipe **72***b* connected to the water/oil tank **20'**, thus whether the surplus emulsion fuel from the diesel engine **70** is returned to the emulsion generator **50** or the water/oil tank **20'** is switchable by a valve.

[0198] The surplus emulsion fuel returned to the water/oil tank **20'** is, as in the case of being returned to the separation tank **80** shown in FIG. **5**, separated into the processed water and the fuel oil by a still-standing treatment in the water/oil tank **20'**. The separated processed water and fuel oil are mixed, respectively, with the processed water supplied from the processed water treatment device **10** and the fuel oil supplied from the crude oil tank **34**, incompletely emulsified in the emulsion generator **50** again, and then supplied to the diesel engine **70**.

[0199] The details on control are the same as those described in the embodiment 1, thus the description thereof is omitted.

EXAMPLES

[0200] Hereinafter, the present invention will be specifically described further based on Examples, however the present invention is not limited to the following Examples.

Test Examples 1 to 7 Characteristic Analysis of Processed Water

[0201] In Test Examples 1 to 7, characteristic analysis of the processed water used in the present invention was performed.

Test Example 1 Emulsification Stability of Processed Water

[0202] Tap water was supplied to and passed through the soft water generation device **100** shown in FIG. **2**, and then passed through the ion generator **114** and the obsidian container **116** for 30 minutes for each to obtain processed water of Example 1.

[0203] The processed water of Example 1, tap water, distilled water, and ultrapure water were each put in a beaker, and 2.7 wt. %, 3 wt. %, and 5 wt. % of heavy oil A were separately added to the each beaker. After stirred with a stirrer, emulsion was prepared from each mixture. Emulsification condition in each sample was observed immediately after preparation, after three hours, after one day, and after three days.

[0204] As a result, in the 3 wt. % samples examined immediately after preparation, an oil phase separated from a water phase was not observed only in the processed water sample, while an oil phase separated from a water phase was observed in the distilled water and ultrapure water samples.

[0205] In the 5 wt. % samples, an oil phase separated from a water phase was observed in all of the processed water, distilled water and ultrapure water samples, however a thickness of the oil phase was decreased in the order of: distilled water>ultrapure water>processed water.

[0206] In the 2.7 wt. % samples with the processed water, tap water and ultrapure water, examined three hours, one day, and three days after preparation, more cloudiness caused by emulsification was observed in the order of: ultrapure water>processed water>tap water, demonstrating that a stability after emulsification was higher in the order of: ultrapure water>processed water>tap water.

[0207] Further, in the samples prepared by adding 3 wt. % of heavy oil A to the processed water of Example 1, distilled water, and ultrapure water and stirring each mixture, particle diameter of emulsion particles was measured by a particle diameter measuring device 30 minutes, 40 minutes, and 60 minutes after preparation. Average particle diameter and standard deviation were shown in FIG. **6**.

[0208] As a result of FIG. **6**, when one hour had passed after preparation, there was little difference in variation in the particle diameter among the processed water, distilled water, and ultrapure water. The average particle diameter of emulsion particles was slightly smaller in the distilled water and ultrapure water samples than the processed water sample, however the difference was negligible.

Test Example 2 Surface Tension of Processed Water Treated with Different Conditions

[0209] Tap water was supplied to and passed through the soft water generation device **100** shown in FIG. **2**, and then circulated in the ion generator **114** for 30 minutes, 1 hour, and 3 hours to obtain processed water of Examples 2 to 4. Tap water was supplied to and passed through the soft water generation device **100** shown in FIG. **1**, and then circulated in the obsidian container **116** for 30 minutes, 1 hour, 3 hours, 4 hours, and 5 hours to obtain processed water of Examples 5 to 9.

[0210] The processed water of Examples 2 to 9 and ultrapure water were measured for surface tension under a sample temperature condition of 26.0° C. at the time of measurement.

[0211] A result is shown in FIG. **7**. From the result of FIG. **7**, the processed water of Examples 2 to 4, circulated in the ion generator **114** for 30 minutes, 1 hour, and 3 hours, and the processed water of Examples 5, 6, and 8, circulated in the obsidian container **116** for 30 minutes, 1 hour, and 4 hours, showed the same level of surface tension as ultrapure water.

Test Example 3 Surface Tension of Processed Water Treated with Different Conditions

[0212] Tap water was supplied to and passed through the soft water generation device **100** shown in FIG. **2**, and then passed through the obsidian container **116** for 5 hours to obtain processed water of Example 10.

[0213] Further, tap water was supplied to and passed through the soft water generation device **100** shown in FIG. **1**, and then passed through both the ion generator **114** and the obsidian container **116** to obtain processed water of Example 11.

[0214] The processed water of Examples 10 and 11, ultrapure water, raw water (tap water) used for preparing Examples 10 and 11, and surfactant-added tap water in which a surfactant was added to the raw water (tap water) were measured for surface tension at a sample temperature of 26.0° C. at the time of measurement.

[0215] A result was shown in FIG. **8**. From the result of FIG. **8**, the processed water of Examples 10 and 11 showed a value of surface tension higher than the raw water, but lower than the ultrapure water. The surfactant-added tap water showed a value of surface tension significantly lower than other samples. The processed water of Examples 10 and 11 showed a value of surface tension similar to the ultrapure water and the raw water, but significantly higher than the surfactant-added tap water.

[0216] From the results of FIGS. **7** and **8**, the processed water of Examples 2 to 11 showed a value of surface tension close to the ultrapure water, demonstrating that the processed water is extremely clean water.

Test Example 4 Zeta Potential of Emulsion

[0217] Heavy oil A was added to the processed water of Example 1 prepared in Test Example 1, ultrapure water, ion exchange water passing through an anion exchange resin, and distilled water, and each mixture was stirred to obtain emulsion of each sample. Zeta potential of these emulsion samples was measured by using a zeta potential measuring device.

[0218] A measurement result is shown in Table 1.

TABLE 1

	Ultrapure water	Ion exchange water	Distilled water	Processed water
Zeta potential [mV]	21.2	20.6	20.3	−33.0

[0219] From a result of Table 1, zeta potential of the processed water was 33 mV expressed by an absolute value, and there was no significant difference from others, however a particle surface charge of the processed water was negative, while a particle surface charge of the other samples was positive. This demonstrated that negative ions existed in the processed water.

Test Example 5 Ion Chromatograph

[0220] The processed water of Example 1 prepared in Test Example 1 and raw water (tap water) of the processed water were subjected to an ion chromatograph method for analyzing anion and an ion chromatograph method for analyzing cation by using an ion chromatograph.

[0221] A measurement result is shown in FIG. **9**. In FIG. **9**, an upper part in each graph shows a measurement result of the processed water, while a lower part shows a measurement result of the raw water.

[0222] From the result of FIG. **9**, in the processed water of Example 1, Mg ions and Ca ions were removed and Na ions are increased fourfold as compared to the raw water (tap water).

Test Example 6 Surface Activity Measuring Test of Processed Water

[0223] Tap water was supplied to and passed through the soft water generation device **100** shown in FIG. **1**, and then passed through the ion generator **114** and the obsidian container **116** sequentially for 5 minutes for each to obtain processed water of Comparative Example 1, or sequentially for 15 minutes for each to obtain processed water of Example 12.

[0224] To each of the sample water thus prepared and tap water (raw water), 2 wt. % of salad oil (triglyceride of oleic acid) was added, and each mixture was shaken and stirred for one minute. After left for 5 minutes, the samples were measured for a ^{1}H-NMR spectrum at a measurement temperature of 22° C. and a measurement frequency of 400 MHz using a Fourier-transform nuclear magnetic resonance device (FT-NMR, Model JNM-EX400, manufactured by JEOL Ltd.) to calculate a quantity of the salad oil dissolved in the each sample water. As a reference matter for concentration measurement, 1 mMol of TSP-d_4 (trimethylsilyl propionic acid) was added.

[0225] The processed water of Example 12 had a measurement value of 127.0, and a quantity of the salad oil dissolved in the water is 20.06 mMol, showing that 2.5 times more salad oil was dissolved as compared to the tap water. In contrast, the processed water of Comparative Example 1 had a measurement value of 74.9, and a quantity of the salad oil dissolved in the water is 11.83 mMol, showing that 1.5 times more salad oil was dissolved as compared to the tap water.

Test Example 7 Measuring Test of Dissolved Oxygen Quantity, Etc.

[0226] In accordance with Drinking Water Testing Methods (2011 Edition), pH, dissolved oxygen quantity, Na ion concentration, and oxidation-reduction potential were measured with the following samples: the processed water of Example 1 in which tap water (city water supply in Ueda city, Japan) was supplied to and passed through the soft water generation device **100** shown in FIG. **2**, and then circulated in the ion generator **114** and in the obsidian container **116** for 30 minutes for each; the processed water of Example 2 in which tap water (city water supply in Ueda city) was supplied to and passed through the soft water generation device **100** shown in FIG. **2**, and then circulated in the ion generator **114** for 30 minutes; the processed water of Example 5 in which tap water (city water supply in Ueda city) was supplied to and passed through the soft water generation device **100** shown in FIG. **1**, and then circulated in the obsidian container **116** for 30 minutes; processed water of Comparative Example 2 in which tap water (city water supply in Ueda city) was supplied to and passed through the soft water generation device **100** shown in FIG. **2**; and the tap water (city water supply in Ueda city) of Comparative Example 3 as raw water of the processed water of Examples 1, 2, and 5, and Comparative Example 2.

[0227] A result is shown in Table 2.

TABLE 2

	pH	Dissolved oxygen [mg/L]	Na ion [mg/L]	Oxidation-reduction potential [mV]
Example 1	7.5 (13.9° C.)	13	32	305
Example 2	7.6 (14.2° C.)	12	30	297
Example 5	7.5 (13.9° C.)	13	32	240
Comparative Example 2	7.9 (23.9° C.)	8.0	36	668
Comparative Example 3	7.9 (23.5° C.)	7.6	9.2	688

[0228] A saturation dissolved oxygen quantity of pure water is 10.2 mg/L under a condition of 1 atom and 13° C., 9.98 mg/L under a condition of 1 atom and 14° C., 8.38 mg/L under a condition of 1 atom and 23° C., and 8.25 mg/L under a condition of 1 atom and 24° C.

[0229] Therefore, dissolved oxygen quantities in Comparative Examples 2 and 3 showed slightly lower values than the saturation dissolved oxygen quantity of pure water. In contrast, dissolved oxygen quantities in all of Examples 1, 2 and 5 showed higher values than the saturation dissolved oxygen quantity of pure water, demonstrating that the processed water of the present invention dissolved more oxygen than the saturation dissolved oxygen quantity of pure water.

Discussion on Test Examples 1 to 7

[0230] The processed water applied to Examples of the present invention was more easily emulsified than distilled water and ultrapure water and showed a zeta-potential value with a negative sign. Further, Mg ions and Ca ions were not contained, while Na ions were increased.

[0231] From these results, it was found that Mg ions and Ca ions that bind to an oil component were absent in the processed water, thus when the processed water and the oil were mixed, a fatty acid was liberated by hydrolysis of a triglyceride contained in the oil and reacts with Na ions to produce a fatty acid sodium salt as a surfactant.

[0232] Further, the processed water applied to Examples of the present invention had surface tension close to that of ultrapure water. However, it was found that, despite having high surface tension, the processed water had a special property, namely that, when mixed with oil without adding a surfactant separately, the processed water exhibited an ability of being emulsified with the oil by synthesizing a surfactant by itself.

[0233] Further it was found that the processed water applied to Examples of the present invention dissolved more oxygen than the saturation dissolved oxygen quantity of pure water. Dissolved oxygen can be a factor for improving combustion efficiency of the emulsion fuel prepared by emulsifying with the fuel oil.

Test Example 8 Heat Generation Quantity of Emulsion Fuel

[0234] In the present Test Example, the emulsion fuel according to the Example of the present invention was measured for a heat generation quantity.

[0235] The processed water of Example 1 obtained in Test Example 1 and heavy oil A were mixed in a beaker of 300 ml at a predetermined ratio (mass ratio) and stirred at 200 to 400 rpm with a propeller-type stirrer. A sample obtained by stirring was enclosed in a capsule and ignited in a sealed container filled with the air to measure a heat generation quantity. Measurements were performed seven times in each sample.

[0236] Using a heat generation quantity A (kJ/kg) of water-free heavy oil A, a measurement value B (kJ/kg) of a heat generation quantity of emulsion, and a mass ratio a of the heavy oil A in the emulsion, an increase rate C of a heat generation quantity caused by processed water was calculated by the following formula.

$$C=B/(A\times a)$$

[0237] As a result, it was found that an average increase rate was 0.071 when a mass ratio of the processed water in the emulsion was 30%, an average increase rate was 0.126 when 40%, an average increase rate was 0.237 when 50%, and an average increase rate was 0.275 when 60%, thus a heat generation quantity was improved by 20% or more by mixing the processed water into the emulsion by 50% or more for emulsification.

Test Example 9 Operation Test of Generator

[0238] By using the emulsion fuel supply device **1** of the embodiment, the emulsion fuel was supplied to a compact generator and a diesel generator, and operation tests of the compact generator and the diesel generator were performed.

[0239] As a result, a power generating time of the compact generator (load: two blowers: 4.3 A) with 40 ml of gasoline was 188 seconds, while a power generating time of the compact generator (load: two blowers: 4.3 A) with the emulsion fuel of the present invention in which 2 ml of the processed water was added to 40 ml of gasoline was 266 seconds (extended by 41%).

[0240] Further, a power generating time of the diesel generator (load: seven projectors: 30 A) with 100 ml of heavy oil A was 129 seconds, while a power generating time of the diesel generator (load: seven projectors: 30 A) with the emulsion fuel of the present invention in which 40 ml of the processed water was added to 100 ml of heavy oil A was 234 seconds (extended by 81%).

[0241] From the above, it was found that when the generators were operated with the emulsion fuel of the present invention, the generators could be operated for a longer time with the same quantity of the fuel oil as compared to the case where the generators were operated with the fuel oil only. As such, it was found that the fuel oil could be saved by 41% or more by using the emulsion fuel of the present invention.

[0242] Further, after the operation tests of the generators were continued for one year, there was no failure, such as breakdown, rusting, and shortened lifetime of the generators, in the compact generator and the diesel generator.

REFERENCE SIGNS LIST

[0243] **1**, **1'**: Emulsion fuel supply devices
[0244] **10**: Processed water treatment device
[0245] **20**: Processed water tank
[0246] **20'**: Water/oil tank
[0247] **21**, **31**: Introduction pipes
[0248] **21***a*, **31***a*: Valves
[0249] **22**, **22'**: Water supply pipes
[0250] **23**, **33**: Ball taps
[0251] **25**, **25'**, **35'**: Electromagnetic valves
[0252] **27**, **37**: Flow rate control valves
[0253] **28**, **38**: Flow rate sensors
[0254] **30**: Fuel oil tank
[0255] **32**. **32'**: Oil supply pipes
[0256] **33'**: Float
[0257] **34**: Crude oil tank
[0258] **36**, **42**: Filters
[0259] **40**, **40'**: Liquid feed parts
[0260] **41**, **41'**: Liquid feed pipes
[0261] **43**: Scale
[0262] **50**: Emulsion generator
[0263] **51**, **54**, **57**: Housings
[0264] **51***a*, **58***b*: Connection parts

[0265] **52**, **55**, **58**: Large-diameter spaces
[0266] **53**, **56**: Closing parts
[0267] **53***a*, **56***a*: Fine holes
[0268] **59**: Return emulsion introduction port
[0269] **60**: Oxygen gas cylinder
[0270] **61**: Oxygen introduction pipe
[0271] **62**: Electromagnetic valve
[0272] **63**: Flow rate measuring instrument
[0273] **70**: Diesel engine
[0274] **71**: Supply pipe
[0275] **73**: Air suction port
[0276] **76**: Pump
[0277] **100**: Soft water generation device
[0278] **110**: First soft water generator
[0279] **112**: Second soft water generator
[0280] **114**: Ion generator
[0281] **116**: Obsidian container
[0282] **118***a*, **118***b*, **118***c*: Communication pipes
[0283] **120**: Water supply pipe
[0284] **122**: Communication pipe
[0285] **124**: Inlet open/close valve
[0286] **126**: Check valve
[0287] **128**: Discharge pipe
[0288] **130**: Outlet open/close valve
[0289] **132**: Ion exchange resin
[0290] **140**: Surface tension increasing device

1. An emulsion fuel supply device for supplying an emulsion fuel having an aqueous phase and an oil phase of a fuel oil to a combustion apparatus, comprising:

a processed water generation device for producing processed water by removing, from raw water, Ca ions and Mg ions contained in the raw water and allowing to remain or adding Na ions in the raw water;

a tank for storing the processed water supplied from the processed water generation device and the fuel oil;

a merging section for merging the fuel oil supplied from the tank and the processed water supplied from the tank at a predetermined flow rate ratio;

an emulsion generation section for producing the emulsion fuel from a mixture of the fuel oil and the processed water merged by the merging section; and

a supply section for supplying the emulsion fuel produced by the emulsion generation section to the combustion apparatus, wherein:

the emulsion generation section comprises a dispersion part comprising fine hole parts comprising a through-hole with small diameter and a cylindrical large-diameter part continuously installed downstream of the fine hole parts; and

the fine hole parts are inclined relative to an extended direction of the emulsion generation section.

2. The emulsion fuel supply device according to claim **1**, wherein:

the tank is a single tank storing the processed water and the fuel oil, comprising a water supply pipe comprising a liquid suction port arranged near a bottom part of the tank and an oil supply pipe comprising a liquid suction port attached on a float floating on the surface of a liquid stored in the tank; and

the merging section alternately performs a supply of the processed water from the water supply pipe and a supply of the fuel oil from the oil supply pipe to merge the fuel oil and the processed water.

3. The emulsion fuel supply device according to claim **1**, wherein:

the tank comprises a water tank for storing the processed water supplied from the processed water generation device and a fuel oil tank for storing the fuel oil, formed as a separate part from the water tank;

the tank comprises an in-tank liquid height adjusting device for adjusting the difference between the height from a bottom surface of the fuel oil tank to a liquid surface of the fuel oil and the height from a bottom surface of the water tank to a water surface of the processed water to be within a predetermined range; and

the merging section merges the fuel oil supplied from the fuel oil tank and the processed water supplied from the water tank with a predetermined flow rate ratio.

4. The emulsion fuel supply device according to claim **3**, wherein:

the water tank and the fuel oil tank are arranged at a position higher than the combustion apparatus;

a supply passage for the processed water and the fuel oil from the water tank and the fuel oil tank to the emulsion generation section is a pump-less passage without a pump; and

the fuel oil and the processed water are supplied to the emulsion generation section by gravity caused by the height difference between the water tank and the fuel oil tank, and the combustion apparatus, and pressure caused by a pump provided in the combustion apparatus.

5. The emulsion fuel supply device according to claim **1**, wherein the emulsion generation section comprises:

a plurality of the dispersion parts each comprising the fine hole parts and the large-diameter part, the plurality of the dispersion parts being continuously connected to each other in series; and

an introduction port for returning surplus fuel discharged from the combustion apparatus to the large-diameter part of the emulsion generation section.

6. The emulsion fuel supply device according to claim **1**, wherein the processed water generation device comprises:

a soft water generation device for producing soft water from raw water, comprising an ion exchanger for removing Ca ions, Mg ions, and Fe ions from the raw water and adding Na ions in the raw water, a tourmaline container for storing tourmaline, and an obsidian container for storing obsidian;

a surface tension increasing section comprising an introduction pipe for introducing the soft water produced in the soft water generation device and a circulation device for circulating the soft water introduced from the introduction pipe into at least one of the tourmaline container and the obsidian container for 30 minutes or more; and

a processed water supply section for supplying processed water having passed through the surface tension increasing section to the water tank.

7. The emulsion fuel supply device according to claim **1**, wherein an air suction port of the combustion apparatus are connected to a gas supply quantity adjusting section for adjusting a supply quantity of gas to the combustion apparatus within a range of zero to a misfiring air quantity as fuel oil being supplied, beyond which a misfire is caused when a water-free fuel oil is supplied, and an oxygen gas supply section for supplying oxygen gas.

8. The emulsion fuel supply device according to claim **1**, wherein the merging section comprises a section for alternately performing a supply of the processed water from the tank to the emulsion generation section and a supply of the fuel oil from the tank to the emulsion generation section.

9. An emulsion fuel supply method for supplying an emulsion fuel having an aqueous phase and an oil phase of a fuel oil to a combustion apparatus, comprising:

a processed water generation step for producing processed water by removing, from raw water, Ca ions and Mg ions contained in the raw water and allowing to remain or adding Na ions in the raw water;

a merging step for merging the fuel oil supplied from a tank storing the processed water produced in the processed water generation step and the fuel oil, and the processed water supplied from the tank at a predetermined flow rate ratio;

an emulsion generation step for producing the emulsion fuel by supplying a mixture of the fuel oil and the processed water merged in the merging step to an emulsion generation section comprising a through-hole with small diameter and a cylindrical large-diameter part continuously installed downstream of the fine hole parts, the fine hole parts being inclined relative to an extended direction of the emulsion generation section; and

a supply step for supplying the emulsion fuel produced in the emulsion generation step to the combustion apparatus.

10. The emulsion fuel supply method according to claim **9**, wherein, in the merging step, the processed water and the fuel oil are merged by alternately performing a supply from a water supply pipe comprising a suction port arranged near a bottom part of the tank and a supply from an oil supply pipe comprising a suction port attached on a float floating on the surface of a liquid stored in the tank.

11. The emulsion fuel supply method according to claim **9**, wherein:

before the merging step, the emulsion fuel supply method comprises an in-tank liquid height adjusting step for adjusting the difference between the height from a bottom surface of a water tank storing the processed water supplied after being produced in the processed water generation step to a water surface of the processed water, and the height from a bottom surface of a fuel oil tank storing the fuel oil to a liquid surface of the fuel oil, to be within a predetermined range; and

in the merging step, the fuel oil supplied from the fuel oil tank and the processed water supplied from the water tank are merged at a predetermined flow rate ratio.

12. The emulsion fuel supply method according to claim **11**, wherein, in the merging step and the emulsion generation step, the fuel oil and the processed water are supplied to the emulsion generation section by gravity caused by the height difference between the water tank and the fuel oil tank arranged at a position higher than the combustion apparatus, and the combustion apparatus, and pressure caused by a pump provided in the combustion apparatus.

13. The emulsion fuel supply method according to claim **9**, wherein, in the emulsion generation step:

a mixture of the fuel oil and the processed water merged in the merging step are allowed to pass through the emulsion generation section comprising a plurality of dispersion parts each comprising fine hole parts comprising a through-hole with small diameter and a cylindrical large-diameter part continuously installed downstream of the fine hole parts, the plurality of the dispersion parts being continuously connected to each other in series; and also

surplus fuel discharged from the combustion apparatus is returned to the large-diameter part of the emulsion generation section.

14. The emulsion fuel supply method according to claim **9**, wherein, in the processed water generation step, Mg ions, Ca ions, and Fe ions contained in the raw water are removed from the raw water by ion exchange, and then the raw water is allowed to pass through at least one of a tourmaline container filled with tourmaline and an obsidian container filled with obsidian to produce the processed water.

15. The emulsion fuel supply method according to claim **14**, wherein, in the processed water generation step, Na ion concentration in the processed water is increased more than Na ion concentration in the raw water.

16. The emulsion fuel supply method according to claim **15**, wherein, in the processed water generation step, surface tension of the processed water measured at a water temperature of 26° C. is adjusted to 50 mN/m or more.

17. The emulsion fuel supply method according to claim **9**, wherein, in the supply step, gas is supplied to the combustion apparatus in a supply quantity within a range of zero to a misfiring air quantity as fuel oil being supplied, beyond which a misfire is caused when a water-free fuel oil is supplied.

* * * * *