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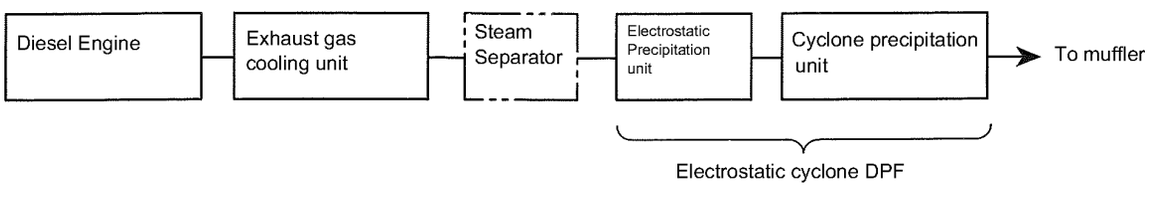
(54) ELECTRIC EXHAUST GAS TREATING METHOD AND ELECTRIC EXHAUST GAS TREATING DEVICE

(57) Problems in conventional exhaust gas treatment techniques for a diesel engine that use corona discharge are solved, and a method and equipment of electrical treatment for diesel engine exhaust gas are provided which can remove with high efficiency PM, particularly, SOF in exhaust gas of a diesel engine using a low-quality fuel equivalent or inferior to heavy fuel oil, and which can provide long-term stable performance. In an electrical exhaust gas treatment method for a large-displacement diesel engine that removes, by an electrical means, particulate matter mainly including insoluble organic fractions and soluble organic fractions contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, the particulate matter is removed by the electrical means after the temperature of the whole exhaust gas containing the particulate matter is lowered by 100˚C or more, preferably, 130˚C or more, to a temperature that is represented by a ratio R of exhaust gas temperature/fuel boiling point temperature of 0.85, or less by a gas cooling means.

FIG. 3



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Description

Technical Field

[0001] The present invention relates to an exhaust gas treatment technique, specifically for a large-displacement diesel engine for a ship, a power generation, an industry, or the like that uses a low-quality fuel equivalent or inferior to heavy fuel oil, to remove particulate matter (hereinafter called "PM") mainly composed of carbon or harmful gas contained in exhaust gas of a diesel engine and purify the same, and in particular relates to an electrical treatment method and an electrical treatment equipment for exhaust gas that utilizes corona discharge in a large-displacement diesel engine that exhausts high-temperature exhaust gas.

Background Art

[0002] Diesel engines are widely adopted as power sources for various ships, power generators, and construction equipments, and further various automobiles or the like, but the PM contained in exhaust gas from the diesel engines not only causes air pollution but also is matter that is extremely harmful to the human body, as is well known, so that purification of the exhaust gas is extremely important. Therefore, many suggestions, such as improvement of combustion systems of diesel engines, adoption of various exhaust gas filters, electrical control treatment methods utilizing corona discharge, and the like have already been made, and some of them are in practical use.

[0003] Of such exhaust gas purification techniques, the electrical treatment method utilizing corona discharge is such that the PM in exhaust gas is charged by corona discharge performed by a discharge electrode and the charged PM is collected by electrostatic force, but, since several tens of thousands of volts are applied to the discharge electrode and further the discharge electrode is exposed to corrosive exhaust gas, long-term stable performance retention is demanded. Further, efficient electrostatic collection of the charged PM is demanded.

[0004] Here, the components of the PM (particulate matter) in exhaust gas of the diesel engines are divided into two components of soluble organic fractions (hereinafter called "SOF") and insoluble organic fractions (hereinafter called "ISF"), and, of them, the SOF component includes unburnt fuel or lubricant as a main component, and contains harmful matter, such as polycyclic aromatics that have a carcinogenic action. On the other hand, the ISF component includes carbon (soot) having low electrical resistivity and sulfate component as main components, and in view of the effects of the SOF component and the ISF component on the human body and the environment, it is desired that the exhaust gas contains the SOF component and the ISF component reduced as much as possible. In particular, it is also said that the degree of a harmful effect of the PM in the human body is particularly problematic when the PM is of a nanometer particle size.

[0005] Therefore, the present inventors previously suggested an electrostatic-cyclone type diesel particulate filter (hereinafter called "DPF") composed of a combination of an electrostatic precipitator and a cyclone precipitator as means for collecting and removing PM mainly including the SOF component and the ISF component in exhaust gas of a diesel engine (see Patent Document 1). In this DPF, a structure by which the insulation performance of a discharge electrode that performs corona discharge even at a high voltage of DC 50 kV that makes it possible to collect PM containing carbon having low electrical resistivity in electrostatic precipitation is maintained for a long period of time is proposed. That is, this DPF, the structure of which is shown in FIG. 6, is composed of an exhaust gas guide pipe 7 provided so as to project from a main body wall 1-1 of a main body of the DPF into the main body; a seal gas pipe 5 which is inserted so as to penetrate through a peripheral side wall external to the main body wall 1-1 of the exhaust gas guide pipe 7, and which is provided such that a distal end of the seal gas pipe 5 reaches the vicinity of a distal opening portion of the exhaust gas guide pipe 7; a needle electrode 4 which is partially separated from an exhaust gas passage 1 by the seal gas pipe 5, and which is disposed so as to project a distal end of a discharge electrode of the needle electrode 4 from a distal opening portion of the seal gas pipe 5 to a downstream side of the exhaust gas passage 1; a collection plate 3 provided so as to be disposed on the downstream side of the exhaust gas passage 1 in the main body of the DPF; and a high-voltage power supply apparatus 6 which applies high DC voltage to the needle electrode 4, wherein a discharge charge portion composed of a corona discharge portion 2-1 where the needle electrode 4 performs corona discharge to emit electrons 10 and a charge portion 2-2 where particulate matter S mainly composed of carbon in exhaust gas G1 is charged with the discharged coronal electrons 10 is provided, and the collection plate 3 which collects the charged particulate matter S is disposed in the main body wall 1-1 of the main body of the DPF, wherein the needle electrode 4 has a structure by which the insulation performance of the needle electrode 4 of corona discharge can be maintained in the time of application of a high voltage of DC 50 kV in order to make it possible to collect the PM containing carbon having low electrical resistivity in electrostatic precipitation, that is, as shown in FIG. 7, a structure of covering a peripheral portion of the needle electrode 4 with a multi-layered coating layer covered with an insulating material and composed of a first layer insulator coating 4-a, a second layer conductor coating 4-b, and a third layer insulator coating 4-c, with a distal end portion 4-1 projected by a predetermine length from the opening end of the seal gas pipe 5, so that the DPF

contributes significantly to the improvement of the collection efficiency of the PM of exhaust gas of the diesel engine, and the maintenance/continuation of the improved efficiency. Incidentally, the reference numeral 4-d denotes a grounded conductor line, and G2 denotes seal gas.

[0006] On the other hand, as a method of electrostatic precipitation of the charged PM, a diesel particulate filter disclosed in Patent Document 2 is known. In this diesel particulate filter, components intended to be collected are electrically aggregated by actively cooling only a wall face of the precipitation electrode (see FIG. 1 and reference numeral 11a in Patent Document 2) where charged PM is aggregated, and utilizing a liquid SOF component deposited on the wall face of the precipitation electrode as a binder, through the utilization of the property of the SOF component in exhaust gas of becoming viscous mist when being cooled and condensed into liquid, the misty SOF component being aggregated and enlarged by capturing superfine particles according to the "principle of birdlime" and such a property that because electrostatic cohesion action occurs in the vicinity of a precipitation electrode, the electrostatic cohesion action is promoted if the vicinity of a precipitation electrode where the electrostatic cohesion action is carried out can be cooled.

Prior Art Documents

Patent Documents

[0007]

Patent Document 1: JPA-2008-19849
Patent Document 2: Japanese Patent No. 4529013

Disclosure of the Invention

Problem to be solved by the Invention

[0008] In the exhaust gas treatment technique for a diesel engine that utilizes corona discharge or the like to treat the PM in exhaust gas electrically, however, there are problems described below.
That is, in a case where the diesel particulate filter described in Patent Document 1, for example, is used in a large-displacement diesel engine for a power generation, a ship, or the like which has a much larger displacement than an automotive diesel engine that uses light diesel oil having a low sulfur content, and which uses a low-quality fuel equivalent or inferior to heavy fuel oil having a high sulfur content (heavy fuel oil has about 10 to 70 times as high a sulfur content as light diesel oil according to JIS K2204 "Light diesel oil" and K2205 "Heavy fuel oil"), it is required to overcome the problem that the sulfur content in the low-quality fuel equivalent or inferior to heavy fuel oil is not only contained in exhaust gas as the SOF, but also becomes sulfates to corrode engine constituent parts, in particular, exhaust-associated parts.
Further, the technique described in Patent Document 2 for a small-displacement diesel engine for installation in an automobile using light diesel oil that is a fuel of high quality having a low sulfur content is a technique where since the electrostatic cohesion action occurs in the vicinity of the precipitation electrode, it is unnecessary to cool the whole gas and since the electrostatic cohesion action is promoted if the vicinity of precipitation electrode can be cooled, cooling is sequentially performed only in the vicinity of the precipitation electrode to make condensing and liquefying possible, thereby resulting in charging and collecting, but, for a diesel engine which is of a large displacement for a ship using a low-quality fuel equivalent or inferior to heavy fuel oil and which emits exhaust gas having a high flow velocity and a high temperature, or an engine having a large amount of PM emission, the limitation of cooling of the PM in high-temperature exhaust gas to a temperature at which the PM is condensed into liquid to local cooling only in the vicinity of the precipitation electrode provides insufficient cooling performance, which results in insufficient cooling, and if cooling of the PM cannot keep up with the supply of the PM, the PM is not cooled and remains hot, which results in exhaust of exhaust gas containing the PM. Further, in the cooling only in the vicinity of the precipitation electrode, the SOF component and the sulfate component in the exhaust gas flowing in the vicinity thereof are condensed into liquid and collected, but the exhaust gas flowing at a site distant from the precipitation electrode is hardly cooled, and accordingly the SOF component in the exhaust gas is not condensed into liquid. Therefore, the SOF component in the exhaust gas flowing at a site distant from the precipitation electrode is exhausted without being collected. Thus, if the diesel particulate filter described in Patent Document 2, which uses light diesel oil that is a high-quality fuel having a low sulfur content, is used for the large-displacement diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, there is not only the problem of corrosion of engine constituent parts due to the sulfates but also the problem that the PM in exhaust gas, in particular, the SOF component is not sufficiently removed.

[0009] In view of these circumstances, the present inventors solve the above problems of the conventional exhaust gas treatment techniques for a diesel engine that utilizes corona discharge, and provide electrical treatment method and equipment for diesel engine exhaust gas which can remove, with high efficiency, the PM, in particular, the SOF

component or the sulfate component, in exhaust gas of a large-displacement diesel engine particularly using a low-quality fuel equivalent or inferior to heavy fuel oil and emitting exhaust gas at a high flow velocity and/or at a large flow rate, and which can deliver long-term stable performance.

Means for Solving the Problems

[0010] A first aspect of the present invention is an electrical exhaust gas treatment method for a large-displacement diesel engine that removes, by electrical means, particulate matter mainly including an ISF component and an SOF component contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein the particulate matter is removed by the electrical means after the temperature of the whole exhaust gas containing the particulate matter is lowered by 100˚C or more, preferably, 130˚C or more, to a temperature that is represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less by gas cooling means.

[0011] A second aspect of the present invention is an electrical exhaust gas treatment method for a large-displacement diesel engine that removes, by electrical means, particulate matter mainly including an ISF component and an SOF component contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein a gas cooling unit, which lowers the temperature of all the exhaust gas containing the particulate matter by 100˚C or more, preferably, 130˚C or more, to a temperature or less that is represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in electrical exhaust gas treatment equipment, and the particulate matter contained in the exhaust gas having a temperature lowered while passing through the gas cooling unit is charged by the electrical means and removed by collecting the charged particulate matter.

[0012] A third aspect of the present invention is an electrical exhaust gas treatment method for a large-displacement diesel engine that removes, by electrical means, particulate matter mainly including an ISF component and an SOF component contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein a gas cooling unit, which lowers the temperature of the whole exhaust gas containing the particulate matter by 100˚C or more, preferably, 130˚C or more, to a temperature that is represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in electrical exhaust gas treatment equipment, and the particulate matter contained in the exhaust gas having a temperature lowered while passing through the gas cooling unit is charged with electrons emitted by corona discharge, and removed by collecting the charged particulate matter.

[0013] A fourth aspect of the present invention is an electrical exhaust gas treatment method for a large-displacement diesel engine that removes, by electrical means, particulate matter mainly including an ISF component and an SOF component contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein a gas cooling unit, which lowers the temperature of all the exhaust gas containing the particulate matter by 100˚C or more, preferably, 130˚C or more, to a temperature that is represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in electrical exhaust gas treatment equipment, and the particulate matter in which the soluble organic fractions constituting the particulate matter are put into supercooled gaseous states represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85 or less when passing through the gas cooling unit is charged with electrons emitted by corona discharge, and removed by collecting the charged particulate matter.

[0014] In the electrical exhaust gas treatment method of the present invention, as a fifth aspect, it is preferred that condensed water is separated and removed from the exhaust gas passing through the gas cooling unit by a steam separator disposed downstream of the gas cooling unit.

[0015] A sixth aspect of the present invention is electrical exhaust gas treatment equipment for a large-displacement diesel engine for removing, by electrical means, particulate matter mainly including an ISF component and an SOF component contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein a gas cooling unit lowering the temperature of the whole exhaust gas containing the particulate matter by 100˚C or more, preferably, 130˚C or more, to a temperature represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in the treatment equipment, a discharge charge portion provided with a corona discharge portion where electrons are emitted by corona discharge and a charge portion where the emitted corona electrons charge the particulate matter is disposed midstream of the exhaust gas passage, a collection unit collecting the charged particulate matter is disposed downstream of the exhaust gas passage, and, when the exhaust gas passes through the gas cooling unit, the exhaust gas where the soluble organic fractions of the particulate matter are put into supercooled gaseous states represented by a ratio R range of the exhaust gas temperature to the fuel boiling point temperature of 0.85 or less is introduced into the discharge charge portion, and the particulate matter is removed by the electrical means.

[0016] A seventh aspect of the present invention is electrical exhaust gas treatment equipment for a large-displacement

diesel engine for removing, by electrical means, particulate matter mainly including an ISF component and an SOF component contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein a gas cooling unit lowering the temperature of the whole exhaust gas containing the particulate matter by 100˚C or more, preferably, 130˚C or more, to a temperature represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in the treatment equipment, a discharge charge portion provided with a corona discharge portion where a needle electrode whose periphery is coated with a coating having a multilayer structure is placed and electrons are emitted by corona discharge of the needle electrode, and a charge portion where the emitted corona electrons charge the particulate matter is disposed midstream of the exhaust gas passage, a collection unit collecting the charged particulate matter is disposed downstream of the exhaust gas passage, and, when the exhaust gas passes through the gas cooling unit, the exhaust gas where the soluble organic fractions of the particulate matter is put into supercooled gaseous states represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85 or less is introduced into the discharge charge portion, and the particulate matter is removed by the electrical means.

[0017] In the electrical exhaust gas treatment equipment of the present invention, as an eighth aspect, it is preferred that a steam separator separating and removing condensed water from the exhaust gas passing through the gas cooling unit is disposed downstream of the gas cooling unit.

Effects of the Invention

[0018] The electrical treatment method and equipment for exhaust gas of a diesel engine according to the present invention are means for purification treatment for exhaust gas of a diesel engine used widely as a power sources of a ship, a power generator, construction equipment, and various automobiles, and the method and equipment makes it possible to efficiently remove the PM that is harmful particulate matter mainly including the ISF component and the SOF component, such as carbon or sulfates, contained in exhaust gas of a large-displacement diesel engine for a ship, a power generation, industrial equipment, or the like that emit exhaust gas at a high velocity and/or at a large flow rate using a low-quality fuel which is equivalent or inferior to heavy fuel oil and which has a high sulfur content, or a diesel engine using a low-quality fuel which is equivalent or inferior to heavy fuel oil and which emits high-temperature exhaust gas, which can result in achievement of exhaust gas purification efficiency in a high level.

Further, such advantageous effects are achieved as long-term maintainable stable removal with high purification efficiency of PM contained in exhaust gas of a diesel engine using a low-quality fuel equivalent or inferior to heavy fuel oil, and achievement of a substantially maintenance-free state in a diesel engine for the above application, for example, as is required for automotive parts.

Further, since nanometer-size PM particles adversely affecting the human body can be significantly reduced, the present invention contributes to the improvement of atmospheric environment.

It should be noted that it goes without saying that the electrical treatment method and equipment for exhaust gas according to the present invention is applicable to purification of exhaust gas in not only diesel engines but also in various engines/equipment using a low-quality fuel equivalent or inferior to heavy fuel oil having a high sulfur content.

Brief Description of the Drawings

[0019]

FIG. 1 is a diagram showing a relationship between the temperature of exhaust gas of a diesel engine and the collection efficiency in the present invention;

FIG. 2 is a diagram showing the boiling point of heavy fuel oil used in a diesel engine;

FIG. 3 is a block diagram showing a first embodiment of an arrangement configuration of electrical exhaust gas treatment equipment for a diesel engine according to the present invention;

FIG. 4 is a block diagram showing a second embodiment of an arrangement configuration of electrical exhaust gas treatment equipment for a diesel engine according to the present invention;

FIG. 5 is a diagram showing the particle size distribution of PM particles in Example 1 of the present invention;

FIG. 6 is a schematic sectional view showing an example of an electrostatic precipitator of conventional electrical exhaust gas treatment equipment for a diesel engine; and

FIG. 7 is an enlarged sectional view of a corona discharge electrode portion of the electrical exhaust gas treatment equipment shown in FIG. 6.

Mode for carrying out the Invention

[0020] Regarding an exhaust gas treatment mechanism of a diesel engine, in order to comply with strict regulations

on exhaust gas, the present inventors have intensively researched exhaust gas purification situations with variously improved mechanisms to collect the PM in exhaust gas, through the application of the electrostatic cyclone DPF equipment shown in FIGS. 6 and 7 and exhaust gas cooling means of the present invention described later to an exhaust pipe of a diesel engine.

As a result, the present inventors have found that, by providing a heat exchanger in exhaust gas pipe to cool whole exhaust gas in advance, the level of temperature of exhaust gas introduced into the electrical cyclone DPF significantly affects the PM collection efficiency, as shown in FIG. 1. Here, the PM collection efficiency is defined as "a collection efficiency = 1 - (a PM concentration after DPF treatment) / (a PM concentration before DPF treatment)". Further, the PM concentration was measured by a method in conformity with ISO/DIS8173-1.

It should be noted that the PM in the present invention means all matters collected on a collection filter by the method in conformity with ISO/DIS8173-1.

[0021] In FIG. 1, an all-PM (SOF component + ISF component) collection efficiency is represented as ηPM, an SOF collection efficiency is represented as ηSOF, and an ISF collection efficiency is represented as ηISF. From FIG. 1, it is found that the PM collection efficiency improves as the temperature of exhaust gas decreases. That is, it is found that the all-PM (SOF component + ISF component) collection efficiency rises as the exhaust gas becomes cooler, and that the rising tendency of the all-PM collection efficiency satisfies ISF component < PM < SOF component.

In particular, the SOF component is most affected by the temperature of the exhaust gas, and the SOF collection efficiency (ηSOF) significantly improves as the temperature of the exhaust gas decreases. That is, it is found that when the temperature of the exhaust gas is high, for example, at a temperature of the exhaust gas of over 300˚C, it is difficult to collect the SOF component with high efficiency. On the other hand, it is found that the ISF component is relatively less affected by the temperature of the exhaust gas.

[0022] Here, regarding the temperature tendency of the SOF component collection, according to the reference document "2005 report of examination and research of marine exhaust air pollutant reduction technology (edited by The Japan Institute of Marine Engineering)", The Japan Institute of Marine Engineering, March, 2006, p. 58-60; and the reference document "Marine engineering technician continuous education basic course (edited by The Japan Institute of Marine Engineering) " The Japan Institute of Marine Engineering, July, 2009, p. 315-3170, it is said that since the exhaust gas is sucked with a filter for collection inserted in an exhaust pipe but the exhaust gas passes through the filter at high temperature in the PM concentration measurement method specified by JIS Z8808, the ISF component of the PM in the exhaust gas can be collected but the SOF component cannot be collected by this method.

[0023] The reason why the SOF component cannot be collected is thought to be because the temperature of exhaust gas just emitted from a diesel engine is high, and therefore most of the SOF component is in a gaseous state. This means that a mechanical filter, such as a JIS filter for collection or a ceramic DPF, which can collect solid or liquid particles but cannot collect gas, cannot collect the SOF component.

Therefore, it is thought that when a conventional diesel particulate filter having a mechanism adapted to the treatment of exhaust gas of a small-displacement diesel engine for an automobile or the like is used for a large-displacement diesel engine for a ship, a power generation, industrial equipment, or the like which emits high-temperature exhaust gas at a large flow rate and at high flow velocity, and which has only a small reduction in the temperature of the exhaust gas until the exhaust gas is exhausted outside, the SOF component is not sufficiently removed, since the temperature of exhaust gas immediately before taken into the diesel particulate filter is high and therefore the SOF component in the exhaust gas is in a gaseous state.

[0024] On the other hand, regarding electrostatic precipitation, collectable matter is solid or liquid particles that can be charged with coronal electrons, and gas is not charged and therefore cannot be collected by the electrostatic precipitation.

Accordingly, in order to collect the SOF component by electrostatic precipitation, it can be thought to be necessary that the SOF component in the gaseous state in exhaust gas immediately after exhausted from the engine is condensed into liquid by some action, and is present in an electrostatic precipitation unit (for example, the charge discharge portion 2 shown in FIG. 6, in particular, a region from the charge portion 2-2 to the vicinity of the collection plate 3).

Further, since it is also thought that a gas component composition in the SOF component is increased according to rising of the temperature of exhaust gas, such a temperature tendency of the collection efficiency shown in FIG. 1 can be understood that the collection efficiency of the SOF component lowers according to rising of the temperature of the exhaust gas.

[0025] The following is a description of a collection mechanism for the SOF component and the sulfate component in electrostatic precipitation of the present invention.

FIG. 2 is a diagram showing the boiling points of heavy fuel oils that are hydrocarbons used in diesel engines, where the horizontal axis shows the carbons (C) number in the hydrocarbon contained in the fuel, and the longitudinal axis shows the boiling point of the hydrocarbon. In FIG. 2, the respective boiling points of the hydrocarbons are connected to each other through a curve. In a general chemical formula C_nH_m for hydrocarbon corresponding to the subject of the carbon number n of the horizontal axis, m depends on the chemical structure of a hydrocarbon, for example, C_nH_{2n+2}

for alkanes (chain saturated hydrocarbon), and a general heavy fuel oil whose carbon number n is more than 17 contains more hydrocarbons/polycyclic aromatics having a relatively high boiling point than light diesel oil. It should be noted that the carbon number n of typical light diesel oil satisfies $14 < n < 20$.

[0026] Here, since the SOF component mainly includes unburnt fuel or lubrication oil, the temperature of exhaust gas flowing into the DPF and the boiling point of the fuel will be considered.

On an intake side of the DPF provided in an exhaust piping system of a diesel engine, most of the SOF component is present in a gaseous state if the temperature of exhaust gas is higher than the boiling point of the fuel, or, conversely, the SOF component in exhaust gas is thought to be condensed into liquid if the temperature of exhaust gas is lower than the boiling point of the fuel, but in practice the SOF component remains unstable supercooled gaseous, and therefore it is impossible to collect the SOF component in this gaseous state only with a mechanical collection mechanism, such as a filter for collection or a ceramic filter.

It should be noted that the sulfate component mainly include oxides of sulfur contained in the fuel, and the condensed form of the sulfate component is thought to be the same as that of the SOF component.

[0027] Then, the present inventors, as shown in FIGS. 3 and 4, have provided a cooling unit that cools whole exhaust gas on the side of an intake side of electrical exhaust gas treatment equipment to perform experiments for variously changing the temperature of the whole exhaust gas introduced into the electrical exhaust gas treatment equipment, and consequently have found that the PM collection efficiency is improved by cooling the temperature of the exhaust gas, as shown in FIG. 1.

That is, before the exhaust gas is introduced into the discharge charge portion of the exhaust gas treatment equipment, the degree of cooling of the SOF component (the difference between the boiling point of the SOF component and the temperature of the exhaust gas) is raised by lowering the temperature of the whole exhaust gas, and in this state electrons are emitted toward the exhaust gas by corona discharge, so that the supercooled gaseous SOF component or sulfate component are condensed into liquid by stimulation of the electrons. This phenomenon is thought to be a similar phenomenon to one known as the Wilson chamber. If the liquefied SOF particles are charged by corona discharge, the SOF component can be collected by electrostatic precipitation. The same holds true for the sulfate component. This is the mechanism of collection of the SOF component and the sulfate component in the electrostatic precipitation the present inventors conclude.

According to this mechanism, since the higher the degree of cooling of the SOF component or the sulfate component is, that is, the lower the temperature of the exhaust gas is, the more the condensation of the SOF component or the sulfate component is promoted, the efficiency of collection of the SOF component and the sulfate component is improved.

[0028] Thus, by lowering the temperature of the exhaust gas, the efficiency of collection of the SOF component and the sulfate component is improved. As a method of lowering the temperature of the exhaust gas, it is only necessary to provide a heat exchanger, such as an existing recuperator for a ship, on an intake side of an apparatus performing electrostatic precipitation as an exhaust gas cooling unit. Further, as another exhaust gas cooling unit, it is also possible to apply a method of lowering the temperature in such a manner that a water or seawater sprayer or the like is provided, droplets of the water or seawater are evaporated completely without being aggregated and at this time heat of evaporation is removed from the exhaust gas, but care should be taken in this method because, if the droplets are aggregated without being completely evaporated and remain as droplets, and accumulate in the electrostatic precipitator, the droplets cause corrosion. But, there is a countermeasure available, such as using a corrosion-resistive stainless steel or a sulfuric acid dew-point corrosion resistant steel (for example, a product name: S-TEN1 made by Nippon Steel Corporation) as a material for the precipitator.

[0029] In view of completely evaporating the droplets without causing cohesion, high-temperature water or high-temperature seawater spraying is desired. In this high-temperature spraying, as pointed out in "paragraph 0007 in JPA-2001-132937" of the reference document, first, since the water is high-temperature water, particles of the water droplets do not reach supersaturated vapor pressure, and therefore the water droplets are no aggregated, and can disappear due to evaporation to cool the exhaust gas rapidly, and, secondly, since the viscosity of water lowers to about 1/3 of the viscosity at room temperature, very fine water droplets can be sprayed. Here, in the case of a ship in the sea, it is economically advantageous that material to be sprayed is seawater.

Incidentally, it goes without saying that, as a method of lowering the temperature of the exhaust gas, not only a heat exchanger, such as the recuperator described above, or the water or seawater sprayer is used alone, but also a combination of them may be used.

[0030] In the present invention, the reason why the temperature of the whole exhaust gas discharged from a gas cooling unit and then flowing into the discharge charge portion of the gas treatment equipment is limited to 100˚C or higher is because a large amount of moisture or the like in the exhaust gas is condensed on a collection face at a temperature lower than 100˚C, and PM fine particles deposited on the collection face adhere to the collection face due to the condensed moisture and then become difficult to remove, and becomes difficult to disperse/fly like a sandstorm or snowstorm in a gas stream of the exhaust gas, which makes a subsequent treatment difficult. It should be noted that, in practice, it is preferred in view of post-treatment of the PM fine particles that the temperature of the whole exhaust

gas discharged from the gas cooling unit and then flowing into the discharge charge portion of the gas treatment equipment is about 130˚C at which the drawback described above hardly occurs. Therefore, in the present invention, preferably, the temperature of all the exhaust gas is 130˚C or higher.

Further, by providing a steam separator on a downstream side of the gas cooling unit and on an upstream side of the electrostatic precipitation section, condensed water in which water vapor, SOF component, sulfate component, carbon, and the like generated due to combustion from the exhaust gas passing through the gas cooling unit are suspended can be separated and removed in advance, and therefore the temperature of the whole exhaust gas may be cooled to about 100˚C.

[0031] In the present invention, as an indicator of the degree of cooling of the temperature of the exhaust gas, a ratio R of the exhaust gas temperature to the fuel boiling point temperature, which is defined by the following expression, is used:

[Expression 1]

[0032] Ratio R of exhaust gas temperature to fuel boiling point temperature = (exhaust gas temperature) ÷ (fuel boiling point temperature)

[0033] It should be noted that the temperatures of respective components contained in heavy fuel oil or the like as fuel for a diesel engine are of course different from one another, but, in the present invention, with reference to a component whose carbon number is the lowest in a heavy fuel oil intended to be used, the boiling point of the component is used to calculate the ratio R of exhaust gas temperature/fuel boiling point temperature. The reason is that, since a component whose carbon number is higher has a higher boiling point, the determination of the "ratio R of exhaust gas temperature/fuel boiling point temperature" with reference to the boiling point of the component whose carbon number is the lowest makes higher an average supercooling degree of all components contained in the heavy fuel oil, which results in an advantage in terms of PM collection.

[0034] An appropriate value of this ratio R of exhaust gas temperature/fuel boiling point temperature was determined by an experiment using a marine diesel engine and using a Heavy fuel oil A as fuel. As a component whose carbon number is the lowest in the components of the heavy fuel oil used in the test, heptadecane $C_{17}H_{36}$ (C = 17) was adopted, and with the use of the boiling point (about 300˚C) of heptadecane $C_{17}H_{36}$ the ratio R of exhaust gas temperature/fuel boiling point temperature was calculated. As a result, a preferred range of the ratio R of exhaust gas temperature/fuel boiling point temperature on an intake side of the discharge charge portion performing electrostatic precipitation is 0.85 or less, more preferably, 0.70 or less. The reason is that most of the SOF component and the sulfate component cannot be liquefied when the ratio R of exhaust gas temperature/fuel boiling point temperature exceeds 0.85. That is, the reason is that it is desired that the SOF component that is soluble organic fractions of the PM particles and the sulfate component in the exhaust gas passing through the gas cooling unit are introduced into the discharge charge portion in their supercooled gaseous states in which the ratio R of exhaust gas temperature/fuel boiling point temperature is 0.85 or less, and that if the ratio R of exhaust gas temperature/fuel boiling point temperature exceeds 0.85, most of the SOF component and sulfate component remains in the gaseous state and a sufficient amount of SOF component and sulfate component cannot be formed into the supercooled gaseous state in which the SOF component and the sulfate component are condensed into liquid and charged in the subsequent discharge charge portion, and therefore a satisfactory purification effect cannot be obtained.

[0035] Thus, since the temperature of the whole exhaust gas discharged from a diesel engine on the intake side of the exhaust gas treatment equipment is cooled to a temperature appropriate to the exhaust gas treatment, the present invention collects the PM in the whole exhaust gas efficiently, and, in particular, when the temperature of the exhaust gas is higher than the boiling points of hydrocarbons that are mainly included in a fuel intended to be used, the present invention is more effective. In particular, the present invention produces a remarkable effect in the use of a Heavy fuel oil C containing many crude oil residues that is used as fuel for a large-side large-displacement diesel engine for a ship, a power generation, industrial equipment, or the like that emits exhaust gas at high velocity and/or at a large flow rate, a fuel obtained by heating Heavy fuel oil C or a fuel with a heated Heavy fuel oil A (having a high SOF component or sulfate component content), a high-sulfur fuel obtained by adding hydrogen to tar (pitch), or the like.

[0036] It should be noted that the configuration of the electrical exhaust gas treatment equipment of the present invention may be equipment provided with only the electrostatic precipitation unit composed of the discharge charge portion 2 and the collection plate 3, as shown in FIG. 6, after the gas cooling unit, or equipment provided further with a second collection unit, for example, the cyclone collector in Patent Document 1 or the like after the electrostatic precipitation unit.

Examples

[0037] Next, the present invention will be described in detail with reference to Examples.

In order to confirm the effect of the present invention, the following experiment was performed using a Heavy fuel oil A as fuel and applying the electrical exhaust gas treatment equipment of the present invention to a marine diesel engine. It should be noted that the boiling point (about 300˚C) of heptadecane C17H36 (C = 17) was used as the boiling point of heavy fuel oil in calculation of the ratio R of exhaust gas temperature/fuel boiling point temperature with the [Expression 1] in the following Examples.

In the following Examples, first, the PM collection efficiencies were measured according to the method in conformity with ISO/DIS8173-1.

Next, in order to research the status of collection of nanometer PM particles in exhaust gas, a scanning mobility particle sizer (SMPS) was used to measure the number per unit volume of PM particles having particle diameters of 500 nm or less, and the number of PM particles of exhaust gas immediately after exhausted from the diesel engine and the number of PM particles of exhaust gas after treatment of the whole exhaust gas by the purification method of the present invention were compared with each other. The unit of particle number is represented by numbers/cm^3.

[0038] Further, in Examples 1 to 5 corresponding to the first embodiment, a piece of equipment having an arrangement configuration shown in FIG. 3 using an electrostatic cyclone DPF equipment provided with an electrostatic precipitation unit and a cyclone collection unit was used, and in Examples 6 to 9 corresponding to the second embodiment, a piece of equipment having an arrangement configuration shown in FIG. 4 using an electrostatic precipitation unit provided with a discharge charge portion and a collection plate was used. It should be noted that in each of the Examples an exhaust gas cooling unit composed of a known water-cooling multitubular heat exchanger was used as an exhaust gas cooling method.

Example 1

[0039] In the Example 1 corresponding to the first embodiment, the equipment shown in FIG. 3 was used, and the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured under the conditions that the whole exhaust gas from the engine was cooled by the gas cooling unit so that the temperature of the exhaust gas on an intake side of the DPF became 247˚C, and that the ratio R of exhaust gas temperature/fuel boiling point temperature was set at 0.82. The result is shown in Table 1.

It should be noted that, in Table 1, the temperature of the exhaust gas on the intake side of the DPF represents the temperature of the exhaust gas cooled by the cooling unit in the equipment configurations shown in FIG. 3 or 4. It should also be noted that the collection performance of each Example is evaluated using a mark of "◎" for one with a PM collection efficiency of 80% or more, a SOF collection efficiency of 70% or more, and an ISF collection efficiency of 85% or more; a mark of "○" for one with a PM collection efficiency of 70% or more, a SOF collection efficiency of 60% or more, and an ISF collection efficiency of 80% or more; a mark of "Δ" for one with a PM collection efficiency of 60% or more, a SOF collection efficiency of 50% or more, and an ISF collection efficiency of 70% or more; and a mark of "×" for one with a PM collection efficiency of less than 60%, a SOF collection efficiency of less than 50%, and an ISF collection efficiency of less than 80%.

[0040] Further, in the Example 1, the statuses of collection of nanometer PM particles were measured. The result is shown in FIG. 5. From the result shown in FIG. 5, it is found that, while the distribution status (indicated by a dashed line) of a peak value of the particle number of PM particle contained in the exhaust gas immediately after exhausted from the diesel engine was $(1.5 \times 10^7)/cm^3$, the distribution status (indicated by a solid line) of the number of PM particles after the purification treatment of the preliminarily-cooled exhaust gas was $(1.7 \times 10^6)/cm^3$, and therefore the total number of nanometer-size PM particles was significantly reduced. This is thought to be because, since most of the nanometer-size PM particles are the SOF component or the sulfate component, the SOF component and the sulfate component are condensed by lowering the temperature of the exhaust gas and collected in the electrostatic precipitation unit.

Example 2

[0041] In the Example 2, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 1, except that the temperature of the exhaust gas on the intake side of the DPF was 223˚C and the ratio R of exhaust gas temperature/fuel boiling point temperature was 0.74. The result is also shown in Table 1.

Example 3

[0042] In the Example 3, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 1, except that the temperature of the exhaust gas on the intake side of the DPF was 198˚C and the ratio R of exhaust gas temperature/fuel boiling point

temperature was 0.66. The result is also shown in Table 1.

Example 4

[0043] In the Example 4, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 1, except that the temperature of the exhaust gas on the intake side of the DPF was 177˚C and the ratio R of exhaust gas temperature/fuel boiling point temperature was 0.59. The result is also shown in Table 1.

Example 5

[0044] In the Example 5, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 1, except that the temperature of the exhaust gas on the intake side of the DPF was 155˚C and the ratio R of exhaust gas temperature/fuel boiling point temperature was 0.52. The result is also shown in Table 1.

Example 6

[0045] In the Example 6 corresponding to the second embodiment, the equipment shown in FIG. 4 was used, and the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 1, except that the temperature of the exhaust gas on the intake side of the DPF was 240˚C and the ratio R of exhaust gas temperature/fuel boiling point temperature was 0.80. The result is also shown in Table 1.

Example 7

[0046] In the Example 7, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 6, except that the temperature of the exhaust gas on the intake side of the DPF was 200˚C and the ratio R of exhaust gas temperature/fuel boiling point temperature was 0.67. The result is also shown in Table 1.

Example 8

[0047] In the Example 8, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 6, except that the temperature of the exhaust gas on the intake side of the DPF was 151˚C and the ratio R of exhaust gas temperature/fuel boiling point temperature was 0.50. The result is also shown in Table 1.

Example 9

[0048] In the Example 9, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 6, except that the temperature of the exhaust gas on the intake side of the DPF was 105˚C and the ratio R of exhaust gas temperature/fuel boiling point temperature was 0.35. The result is also shown in Table 1.

(Comparative Example 1)

[0049] In the Comparative Example 1, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 1, except that the temperature of the exhaust gas on the intake side of the DPF was 357˚C and the ratio R of exhaust gas temperature/fuel boiling point temperature was 1.19. The result is also shown in Table 1. This Comparative Example 1 corresponds to an actual case where electrical purification treatment was performed without cooling the exhaust gas.

(Comparative Example 2)

[0050] In the Comparative Example 2, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 1, except that the temperature of the exhaust gas on the intake side of the DPF was 300˚C and the ratio R of exhaust gas temperature/

fuel boiling point temperature was 1.00. The result is also shown in Table 1.

(Comparative Example 3)

[0051] In the Comparative Example 3, the SOF collection efficiency (ηSOF), the PM collection efficiency (ηPM), and the ISF collection efficiency (ηISF) were measured through the same experiment as the Example 1, except that the temperature of the exhaust gas on the intake side of the DPF was 274˚C and the ratio R of the exhaust gas temperature to the fuel boiling point temperature was 0.91. The result is also shown in Table 1.

[0052]

[Table 1]

	Exhaust gas temperature on DPF intake side [˚C]	Ratio R of exhaust gas temperature /fuel boiling point temperature	SOF collection efficiency [%]	PM collection efficiency [%]	ISF collection efficiency [%]	Evaluation
Example 1	247	0.82	62	75	85	○
Example 2	223	0.74	68	78	88	○
Example 3	198	0.66	72	81	89	◎
Example 4	177	0.59	75	82	90	◎
Example 5	155	0.52	78	85	90	◎
Example 6	240	0.80	70	75	82	○
Example 7	200	0.67	78	80	85	◎
Example 8	151	0.50	78	83	87	◎
Example 9	105	0.35	81	87	92	◎
Comparative Example 1	357	1.19	10	32	60	×
Comparative Example 2	300	1.00	38	56	75	×
Comparative Example 3	274	0.91	50	65	80	Δ

[0053] As is obvious from Table 1, when the ratio R of exhaust gas temperature/fuel boiling point temperature was 0.85 or less, a high SOF collection efficiency (ηSOF) of 60% or more, a high PM collection efficiency (ηPM) of 75% or more, and a high ISF collection efficiency (ηISF) of 80% or more were obtained.
On the other hand, in the Comparative Examples where the temperature of the exhaust gas remained high, no satisfactory results were obtained.

[0054] This result shows that, while the average PM emission rate of marine diesel engines is generally about 0.6 g/kWh, the PM emission rate of a ship having the electrical exhaust gas treatment equipment for a large-displacement diesel engine shown in the Examples in which the PM collection efficiency (ηPM) was 75% or more can be reduced to $0.6 \times (1 - 0.75) = 0.15$ g/kWh or less.
This value falls far below the limit value of 0.27 g/kWh based on the 2012 third proposal of emission regulations of the United States where PM emission regulations has already be implemented (see the reference document "2007 report of examination and research of marine exhaust air pollutant reduction technology (edited by The Japan Institute of Marine Engineering) ", The Japan Institute of Marine Engineering, March, 2008, p. 90).

[0055] It should be noted that, in the equipment shown in FIG. 3 used in the Examples 1 to 5, when the thickness of a PM aggregation deposition collected in the electrostatic precipitation unit increases excessively, the PM aggregation deposition are as PM aggregations are separated. The separated PM aggregations are collected by the subsequent cyclone collector into a dust container and accumulated therein. Further, in the case of the equipment shown in FIG. 4 used in the Examples 6 to 9, the PM collected by the electrostatic precipitation unit may be collected into a dust container

by mechanical vibration or a brushing mechanism, and accumulated therein.

Further, the present invention can separate/remove condensed water from the exhaust gas if a steam separator is installed on a downstream side of the exhaust gas cooling unit in the equipment showing FIG. 3 or 4. Since the condensed water is removed in advance, sulfur-derived products or nitrogen-origin products are contained in the condensed water and are removed from the exhaust gas, and the sulfur-derived products or the nitrogen-origin products are absorbed by the ISF (soot) in the PM adhering to the condensed water and are removed, and the PM (SOF and ISF) content in the exhaust gas and the nitrogen-derived product content therein are thus lowered, and therefore the load on the DPF can be reduced, and the possibility that the durability of the engine and associated parts is impaired can be reduced further. Such effects are remarkable particularly when the temperature of the exhaust gas discharged from the exhaust gas cooling unit is around 100˚C. It should be noted that it is not necessary to remove the condensed water completely in the stream separator, and the condensed water may be removed in such a manner that large particles are separated by collision against a baffle (separation plate), and fine particles and solid particles are charged by the subsequent corona discharge and then collected/precipitated by absorption to the collection plate due to coulomb force.

Description of Reference Numerals

[0056]

1: Exhaust gas passage
1-1: Main body wall
2: Discharge charge portion
2-1: Corona discharge portion
2-2: Charge portion
3: Collection plate
4: Needle electrode
4-a: First layer insulator coating
4-b: Second layer conductor coating
4-c: Third layer insulator coating
4-d: Grounded conductor line
5: Seal gas pipe
6: High-voltage power supply
7: Exhaust gas guide pipe
8: PM
10: Corona discharge
G1: Exhaust gas
G2: Seal gas

Claims

1. An electrical exhaust gas treatment method for a large-displacement diesel engine that removes, by electrical means, particulate matter mainly including insoluble organic fractions and soluble organic fractions contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein
the particulate matter is removed by the electrical means after the temperature of the whole exhaust gas containing the particulate matter is lowered by 100˚C or more, preferably, 130˚C or more, to a temperature that is represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less by gas cooling means.

2. An electrical exhaust gas treatment method for a large-displacement diesel engine that removes, by electrical means, particulate matter mainly including insoluble organic fractions and soluble organic fractions contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein
a gas cooling unit, which lowers the temperature of all the exhaust gas by 100˚C or more, preferably, 130˚C or more, to a temperature that is represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in electrical exhaust gas treatment equipment, and the particulate matter contained in the exhaust gas having a temperature lowered when passing through the gas cooling unit is charged by the electrical means and removed by collecting the charged particulate matter.

3. An electrical exhaust gas treatment method for a large-displacement diesel engine that removes, by electrical means, particulate matter mainly including insoluble organic fractions and soluble organic fractions contained in

exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein a gas cooling unit, which lowers the temperature of the whole exhaust gas by 100˚C or more, preferably, 130˚C or more, to a temperature that is represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in electrical exhaust gas treatment equipment, and the particulate matter contained in the exhaust gas having a temperature lowered when passing through the gas cooling unit is charged with electrons emitted by corona discharge, and removed by collecting the charged particulate matter.

4. An electrical exhaust gas treatment method for a large-displacement diesel engine that removes, by electrical means, particulate matter mainly including insoluble organic fractions and soluble organic fractions contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein a gas cooling unit, which lowers the temperature of the whole exhaust gas by 100˚C or more, preferably, 130˚C or more, to a temperature that is represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in electrical exhaust gas treatment equipment, and the particulate matter in which the soluble organic fractions constituting the particulate matter are put into supercooled gaseous states represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85 or less when passing through the gas cooling unit is charged with electrons emitted by corona discharge, and removed by collecting the charged particulate matter.

5. The electrical exhaust gas treatment method according to any one of claims 1 to 4, wherein condensed water is separated and removed from the exhaust gas passing through the gas cooling unit by a steam separator disposed downstream of the gas cooling unit.

6. An electrical exhaust gas treatment equipment for a large-displacement diesel engine for removing, by electrical means, particulate matter mainly including insoluble organic fractions and soluble organic fractions contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein a gas cooling unit lowering the temperature of the whole exhaust gas by 100˚C or more, preferably, 130˚C or more, to a temperature represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in the treatment equipment, a discharge charge portion provided with a corona discharge portion where electrons are emitted by corona discharge and a charge portion where the emitted corona electrons charge the particulate matter is disposed midstream of the exhaust gas passage, a collection unit collecting the charged particulate matter is disposed downstream of the exhaust gas passage, and, when the exhaust gas passes through the gas cooling unit, the exhaust gas where the soluble organic fractions of the particulate matter are put into supercooled gaseous states represented by a ratio R range of the exhaust gas temperature to the fuel boiling point temperature of 0.85 or less is introduced into the discharge charge portion, and the particulate matter is removed by the electrical means.

7. An electrical exhaust gas treatment equipment for a large-displacement diesel engine for removing, by electrical means, particulate matter mainly including insoluble organic fractions and soluble organic fractions contained in exhaust gas of a diesel engine that uses a low-quality fuel equivalent or inferior to heavy fuel oil, wherein a gas cooling unit lowering the temperature of all the exhaust gas by 100˚C or more, preferably, 130˚C or more, to a temperature represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85, or less is disposed upstream of an exhaust gas passage in the treatment equipment, a discharge charge portion provided with a corona discharge portion, where a needle electrode whose periphery is coated with a coating having a multilayer structure is placed and electrons are emitted by corona discharge of the needle electrode, and a charge portion where the emitted corona electrons charge the particulate matter is disposed midstream of the exhaust gas passage, a collection unit collecting the charged particulate matter is disposed downstream of the exhaust gas passage, and, when the exhaust gas passes through the gas cooling unit, the exhaust gas where the soluble organic fractions of the particulate matter are put into supercooled gaseous states represented by a ratio R of the exhaust gas temperature to the fuel boiling point temperature of 0.85 or less is introduced into the discharge charge portion, and the particulate matter is removed by the electrical means.

8. The electrical exhaust gas treatment equipment according to claim 6 or 7, wherein a steam separator separating and removing condensed water from the exhaust gas passing through the gas cooling unit is disposed downstream of the gas cooling unit.

FIG. 1

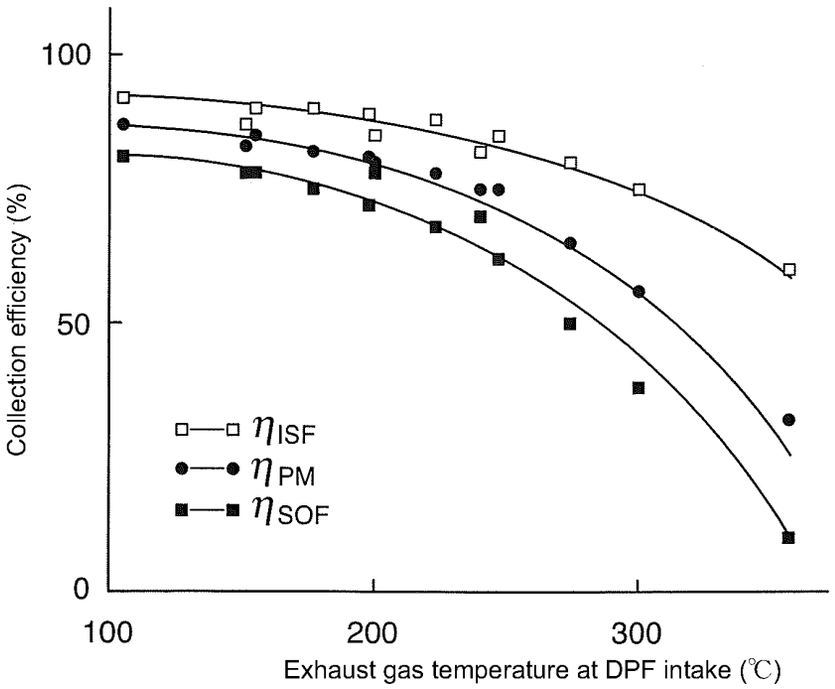

100
50
0
Collection efficiency (%)
η_{ISF}
η_{PM}
η_{SOF}
100
200
300
Exhaust gas temperature at DPF intake (℃)

FIG. 2

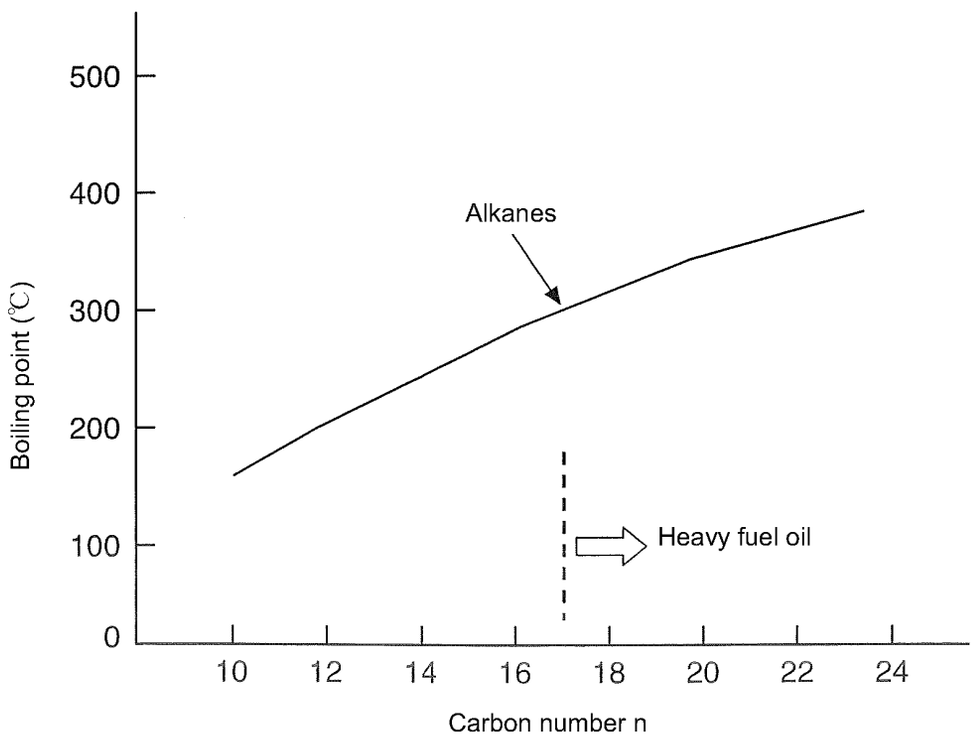

500
400
300
200
100
0
Boiling point (℃)
Alkanes
Heavy fuel oil
10
12
14
16
18
20
22
24
Carbon number n

FIG. 3

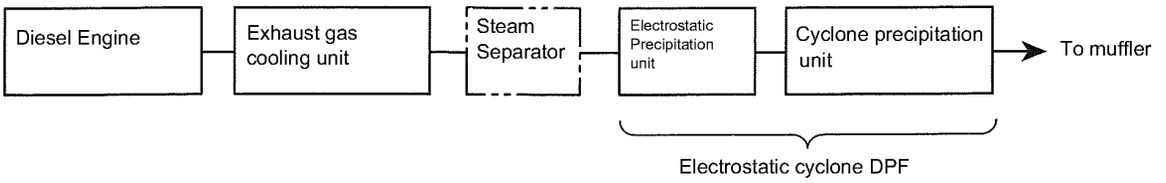


FIG. 4

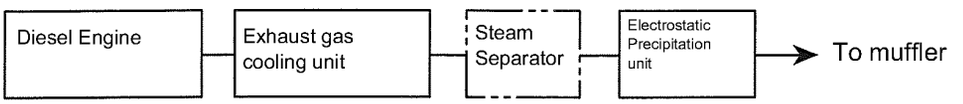


FIG. 5

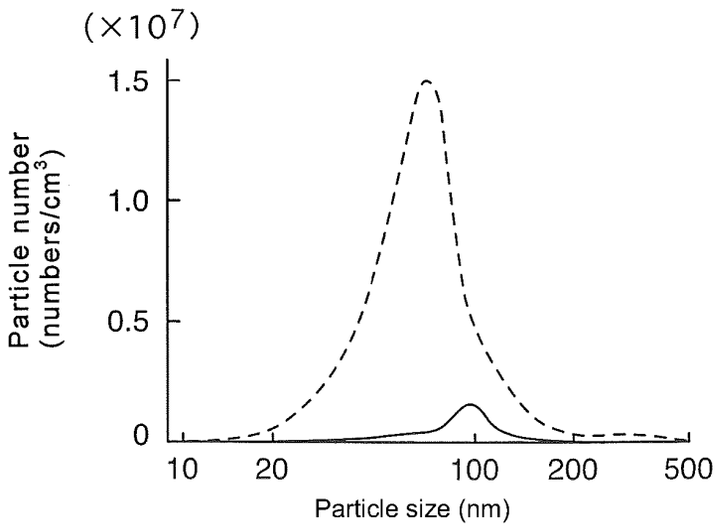


FIG. 6

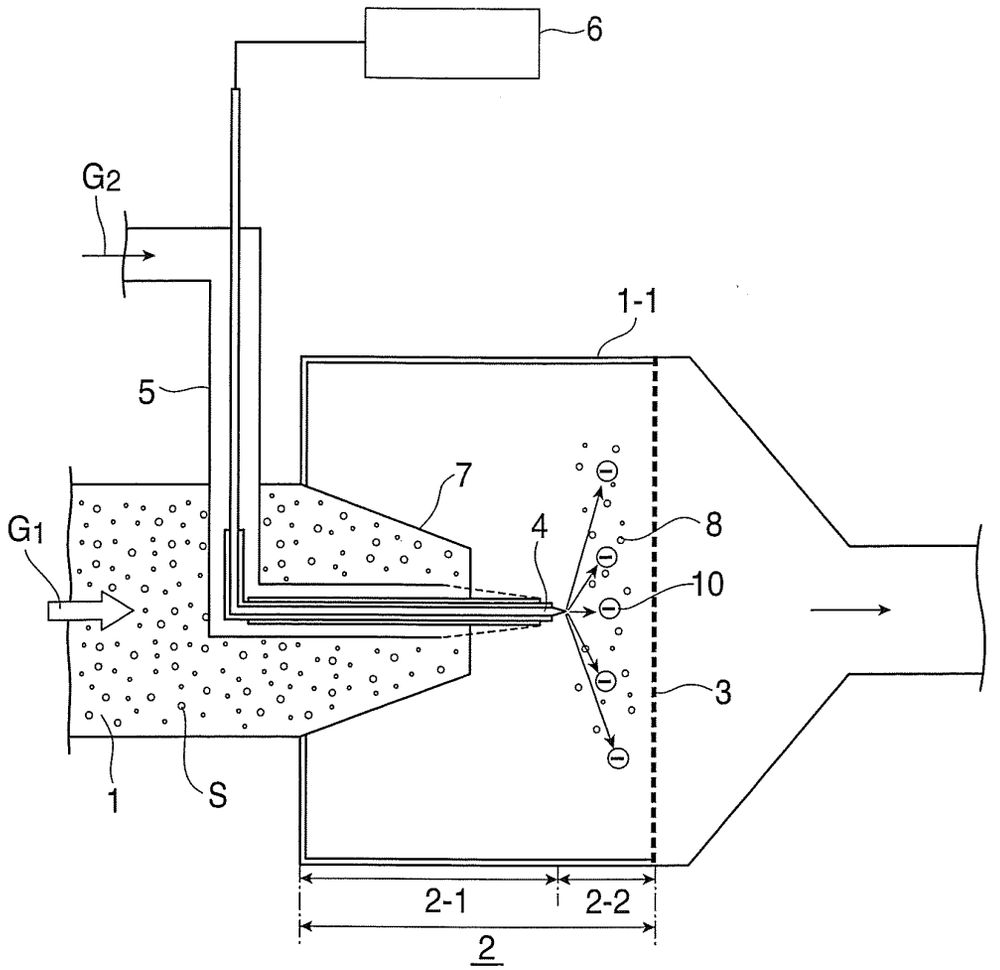
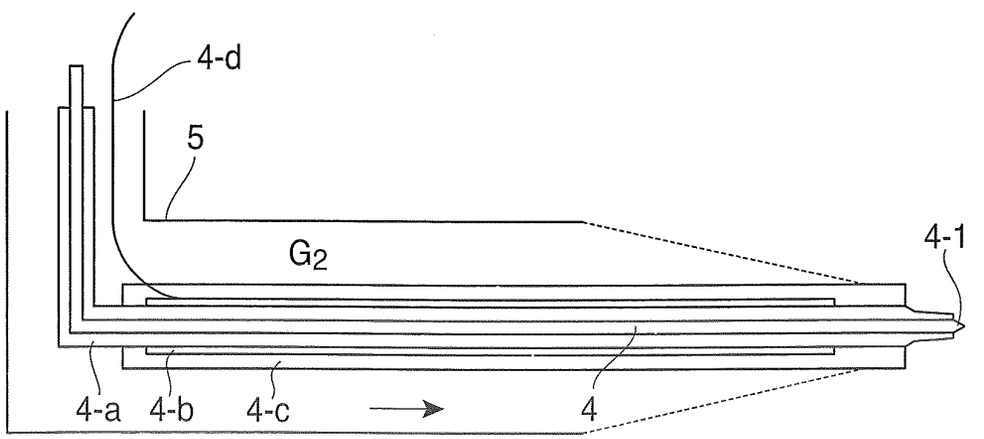


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/068089

A. CLASSIFICATION OF SUBJECT MATTER
F01N3/02(2006.01)i, *B01D51/00*(2006.01)i, *B03C3/15*(2006.01)i, *B03C3/38*(2006.01)i, *B03C3/40*(2006.01)i, *B03C3/41*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01N3/02, B01D51/00, B03C3/15, B03C3/38, B03C3/40, B03C3/41

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 2006-102575 A (Isuzu Motors Ltd.), 20 April 2006 (20.04.2006), paragraph [0027] & US 2007/0261556 A1 paragraph [0028] & EP 1813351 A1 & WO 2006/038461 A1	1-4,6-7

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search 06 December, 2010 (06.12.10)	Date of mailing of the international search report 14 December, 2010 (14.12.10)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/068089

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 56-126613 A (General Motors Corp.), 03 October 1981 (03.10.1981), entire text; all drawings & US 4319453 A & GB 2068258 A & DE 3103374 A & FR 2475119 A1 & CA 1151551 A	1-8
A	JP 2009-52440 A (Hitachi Plant Technologies, Ltd.), 12 March 2009 (12.03.2009), entire text; all drawings (Family: none)	1-8
A	JP 2005-248792 A (Toyota Motor Corp.), 15 September 2005 (15.09.2005), entire text; all drawings (Family: none)	1-8

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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