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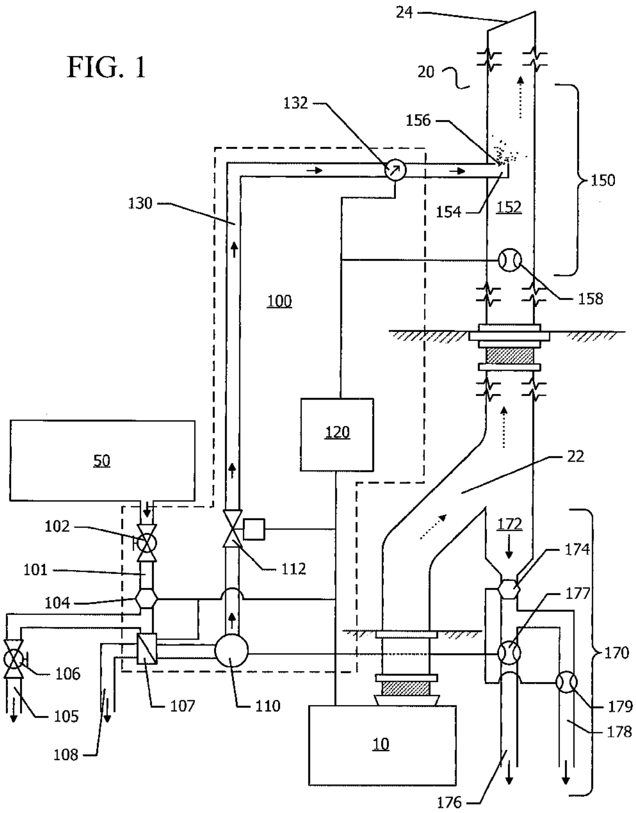
[Continued on next page]

(54) Title: MARINE-BASED WATER PROCESSING AND DISPOSAL SYSTEM AND METHOD

FIG. 1



(57) Abstract: A system and method for processing and disposing of tainted water on a marine vessel includes a vaporization chamber disposed in an exhaust assembly of the vessel and at least one fine spray nozzle positioned therein to direct a spray of water into exhaust gases produced by the engine to thereby vaporize the water. The flow rate of the water to the spray nozzle is determined at least in part by the vaporization rate achievable by the engine exhaust, and in particular by a current operating load of the engine, such as the current throttle position of the engine. The flow rate can be adjusted in response to changes in the engine operating load. Any water not vaporized in the exhaust assembly is collected and redirected to the vessel's bilge or other catchment area.

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MARINE-BASED WATER PROCESSING AND DISPOSAL SYSTEM AND METHOD

Technical Field

[0001] This disclosure relates to marine-based processing and disposal of waste water.

Technical Background

[0002] Sewage water and bilge water generated onboard a marine vessel is expected to be processed through equipment mandated by regulation prior to discharge overboard from the vessel into the sea or other bodies of water. While it is presumed that the onboard equipment will perform as expected to enable the vessel owner or operator to comply with applicable rules and regulations, regulatory compliance remains the burden of the owner or operator to ensure that any water discharged overboard is done at the times and locations where such discharge is permitted, and that any particulate or contaminant concentration in the discharged water is within acceptable limits.

[0003] For example, notwithstanding advances made in oil-water separation technology, many marine vessel owners and operators remain sceptical about the capability and reliability of oil water separation systems to process bilge water to the standard acceptable for discharge overboard from a vessel into the sea or other bodies of water. Furthermore, many regulatory bodies are concerned with the release of sediment, particulates, invasive species, and various forms of bacteria and other contaminants which may remain in processed bilge and sewage water that may otherwise be acceptable for overboard discharge into the sea or other bodies of water.

Brief Description of the Drawings

[0004] In drawings which illustrate by way of example only embodiments of the present disclosure,

[0005] FIG. 1 is a schematic of a first example water treatment and disposal system on a marine vessel.

[0006] FIG. 2 is a block diagram of functional components of the controller of a water treatment and disposal system.

[0007] FIG. 3 is a graph illustrating a relationship between exhaust mass flow in a vaporization chamber and a water disposal rate for a selection of exhaust temperatures.

[0008] FIG. 4 is a table setting out exhaust mass flow characteristics for a first set of engines.

[0009] FIG. 5 is a table setting out exhaust mass flow characteristics for a second set of engines.

[0010] FIG. 6 is a graph illustrating a relationship between water vaporization rates and engine load for a selection of marine engines.

[0011] FIG. 7 is a schematic of a further example water treatment and disposal system on a marine vessel.

Detailed Description

[0012] The day-to-day operation of marine-based structures and vessels involves the generation of potentially tonnes of waste water. Oil-contaminated water can be produced as a result of oil leaks from equipment such as generators and propulsion engines; sewage water is produced by the personnel staffing the structure or vessel; grey water is produced from a range of sources or activities, such as cargo hold washdowns and the like. This waste water must be disposed of, either by discharge overboard into the sea or other body of water, or else by shoreside removal to a holding vessel. Either discharge method presents challenges.

[0013] For instance, local or international regulations may direct how and when certain types of waste water is processed and then discharged overboard. Some states or localities have defined "no discharge zones", prohibiting the discharge of bilge water overboard within a certain range from shore. This is impractical for a marine vessel owner or operator; for example, an operator of a cargo vessel attempting to unload cargo at a port and take on a new load would be required to enter port to unload the cargo; leave port to wash down the cargo hold; then return to port to load new cargo. This results in delays and added costs in reloading and transporting the newly-loaded cargo to its destination. Some states or localities may require bilge water to be discharged shoreside at designated facilities, or onto transport vehicles that carry the waste water away for processing. Again, this imposes additional costs and delays on marine vessel owners and operators.

[0014] From an environmental point of view, the regulations restricting the conditions under which waste water can be discharged from marine vessels are deficient, vis-à-vis the amount of sediment and particulate that may be contained in waste water deemed acceptable for overboard discharge. From an environment and health and safety perspective, the regulations are also deficient regarding the bacteria levels in the discharged water. Indeed, not every form of waste water discharge is regulated; discharge of grey water from some sources is currently unregulated in many states.

[0015] An alternative water disposal system that eliminates or reduces reliance on overboard and shoreside discharges would conserve operating resources of marine vessels and other marine structures that generate waste water, and reduce environmental and health risks associated with overboard discharge of waste water.

[0016] Accordingly, the present disclosure provides a system and method for processing and disposal of tainted waters generated onboard a marine vessel through efficient vaporization of the tainted water in a controlled system. Using the disclosed system and method, the amount of tainted water required to be discharged overboard may be reduced or eliminated altogether. Briefly, water is collected from one or more existing water treatment systems on board the vessel or from other untreated sources (such as untreated grey water) and pumped through injection lines to one or more fine spray nozzles that direct a fine spray of fog or sub-millimetre water droplets into the exhaust stack and the superheated exhaust gases emitted by the vessel's engines. As will be appreciated by those skilled in the art, the exhaust is substantially dry, sufficiently constant in temperature and flow rate while the engine is operating at a given capacity, and has a sufficiently high mass flow rate to accelerate the vaporization of water without the need for heat exchangers to transfer engine waste heat to the water. Due to the small water droplet size, a relatively expansive amount of surface area of the water is exposed to the hot exhaust; and furthermore, the mass flow of the exhaust is sufficient to effectively suspend the water droplets within the stack as the heat of the exhaust is transferred to the water droplet. These factors enhance the rate of vaporization of water injected into the system; and with appropriate selection of an injected water flow rate based on the operating level of the engine, substantially all of the injected water may be vaporized, thus eliminating the need to discharge any of that water overboard in the conventional manner.

[0017] FIG. 1 illustrates a first example of an onboard water processing and disposal system. It will be appreciated by those skilled in the art that the accompanying figures are not drawn to scale and that several features typically present in a vessel have been omitted for clarity in presentation; for instance, various supports used to support or join segments of a marine exhaust stack, such as spring hangers or expansion joints, and components such as silencers are not specifically illustrated or described. It will be appreciated that the systems and methods described herein may be adapted for use in different vessel configurations not specifically depicted herein.

[0018] As shown in FIG. 1, at least one engine 10 is employed for either propulsion or auxiliary power needs, or both. Multiple engines are illustrated with reference to FIG. 7, discussed below. The engine 10 is connected to an exhaust stack of the vessel, here illustrated as exhaust assembly 20. In some of the marine installations contemplated herein, the vessel may be a large passenger or cargo vessel, or other carrier, powered by multiple heavy-duty engines having power outputs ranging from several hundred to several thousand kilowatts, such as the MaK™ line of engines available from suppliers such as Caterpillar Inc. (Peoria, Illinois) or those available from Wärtsilä (Helsinki, Finland). However, it will be understood by those skilled in the art that the inventive concepts described herein may be adapted for use with less powerful engines used in other contexts.

[0019] Exhaust gases emitted by the engine 10 are vented through the exhaust assembly 20 to the stack outlet 24. It will be understood that the exhaust assembly may be constructed from a number of segments of exhaust pipe, and is typically sealed against exhaust gas escape and insulated to reduce heat transfer to the surrounding environment on the vessel. These features are omitted from the figures for ease of reference. However, at least part of the exhaust assembly 20 is optionally angled or curved so as to prevent rainwater, for example, entering the stack outlet 24 from entering the engine exhaust outlet. Thus, the portion of the exhaust stack 20 near the outlet is not necessarily vertically aligned with a lower portion of the stack below deck. The particular configuration of the angled or curved portion of the exhaust assembly 20 may vary according to the particular design of the vessel, and is represented in the accompanying drawings by angled portion 22.

[0020] The example onboard water processing and disposal system can be integrated with the engine exhaust system of the vessel. As shown in FIG. 1, a water holding tank 50 or other collector provides a source of water for processing by the system. The sources of water can include sewage water, bilge water, grey water, and other wastewater that was generated onboard and already processed through the vessel's existing water treatment systems, such as a marine sanitation device or oily water separation system, not illustrated. Other sources of water can include grey water that was not pre-processed onboard, and other waters such as water collected from cargo hold, tank or deck/vessel wash-downs. The water drawn into and processed through the system is generally referred to as "tainted" water herein. The tank 50 illustrated in the figures may be considered representative of one or more of these sources; for example, in some implementations the sole source of tainted water collected for elimination by the system may be water received from the oily water separation system.

[0021] The tank or other collector 50 is in fluid communication with a pump 110 by means of a delivery line 101, preferably by gravity. Generally, it is expected that the diameter of the delivery line 101 is large enough to ensure that the flow rate of tainted water from the tank 50 exceeds the processing rate of the pump 110. To provide for manual control over water delivery from the tank 50 (e.g., as a safety control), a manual valve 102 is provided for controlling flow of the tainted water from the tank 50 to the pump 110.

[0022] Additionally, a self-flushing stainless steel strainer 107 may be interposed between the tank 50 and the intake side of the pump 110 to remove solid waste from the tainted water prior to reaching the pump 110. A flush line 108 collects flush water expelled by the strainer 107 and delivers it to a sediment store, not illustrated. A water level sensor 104 can be mounted on the delivery line 101 on the intake side of the strainer 107 and/or pump 110 to detect whether or not there is a presence of tainted water that must be eliminated from the vessel by the system. Signals from the water level sensor 104 are received by the controller 120. If the water level in the delivery line falls below the level of the water level sensor 104, the controller 120 can close the flow metering valve 112 and deactivate the pump 110. On detection of an overflow condition by the controller 120, an operator of the system can be signalled to shut off the flow of water in the delivery line 101 by closing the manual valve 102 and/or drain water present in the delivery line 101 to the bilge through the purge line 105, by opening valve 106.

[0023] The pump 110 and other components between the intake of the pump 110 and the outlet of the tank 50 are preferably positioned below the level of the tank 50 to provide constant head pressure, which continuously feeds tainted water (by gravity) through the delivery line 101 to the pump 110.

[0024] The pump 110 pumps water into an injection line 130 fitted with a flow metering valve 112. The flow metering valve 112 is equipped with an actuator controlled by the controller 120 responsive to engine conditions and other detected conditions, as discussed below. The flow metering valve 112 controls the rate of tainted water flow, and hence the fluid pressure of the tainted water, in the injection line 130. The injection line 130 can also be fitted with a sensor, such as a pressure sensor 132, between the outlet of the flow metering valve 112 and an outlet end of the injection line 130. The pressure sensor 132 is also in communication with the controller 120. The outlet end of the injection line 130 is in turn connected to a water injector 154 positioned in a shaft 152 of a vaporization chamber portion 150 of the vessel's exhaust assembly 20. The water injector 154 comprises at least one fine spray nozzle 156; depending on the configuration of the water injector 154, more than one fine spray nozzle 156 may be provided. The fine spray nozzles 156 contemplated here refer to misting, fogging, and atomizing spray nozzles configured to provide a fine spray of droplets with diameters in the range of from below 10 μm to about 400 μm, but preferably in the range of about 25 μm to about 400 μm or about 40 μm to about 180 μm, at pump pressures ranging from about 100 PSI to about 400 PSI, depending on the flow rate of tainted water to be processed. Suitable nozzles include misting and air atomizing nozzles from BETE Fog Nozzle, Inc., Greenfield MA, USA.

[0025] The vaporization chamber 150, in these examples, includes a vaporization shaft 152 forming part of the exhaust stack 20 between any angled or bent portion 22 and the outlet 24, or between the engine 10 and the outlet 24 if there is no angled or bent portion 22 of the exhaust stack 20. Exhaust gases emitted by the engine 10 thus rise through the engine stack components including the vaporization shaft 152 towards the outlet 24. As described below, while the engine is operating and exhaust gases are flowing through the stack 20, tainted water is sprayed by the fine spray nozzles 156 into the passing exhaust gases and thereby vaporized. In a further implementation, a static mixer (not illustrated) may optionally be mounted within the exhaust stack 20 proximate to the at least one fine spray nozzle 156. The static mixer may be situated downstream of the at least one fine spray nozzle 156 to receive both the exhaust gas and water spray, and to combine them to produce a mixed stream of exhaust and water spray. An example of a suitable static mixer would include, for instance, the Westfall™ Model 3050 series static mixers. The engine stack 20 may also be provided with a gas flow meter 158, also in communication with the controller 120, to monitor the flow rate of exhaust gases through the stack 20 and shaft 152.

[0026] In the event that water entering the vaporization shaft 152 from the fine spray nozzle(s) 156 is not vaporized but instead falls under the force of gravity through the stack 20 ("overflow water"), a water collection module 170 is also provided to collect this overflow water and sequester the overflow water from the exhaust stream and engine, and discharge it to the vessel's bilge. The water collection module 170 is connected to the stack 20, and positioned below the vaporization chamber 150 and below the junction of the angled or bent portion 22 with the portion of the stack 20 leading to the vaporization chamber 150. A simple example of this configuration is illustrated in FIGS. 1 and 7.

[0027] The water collection module 170 includes an overflow catchment 172, which receives falling overflow water and directs the overflow water to a drain line 176. The drain line 176 is always open and continuously delivers the overflow water to the vessel's bilge by gravity. The drain line 176 is sized to ensure that the flow rate of the overflow water received from the overflow catchment 172 exceeds the processing rate of the pump 110. As an additional safety measure, an overflow line 178 is also fitted to the drain line 176 immediately below the connection to the overflow catchment 172. The overflow line 178, which is also always open, continuously collects excess overflow water, if any, that accumulates in the drain line and also delivers it by gravity to the bilge. One or more of the overflow catchment 172, drain line 176, and overflow line 178 may be provided with one or more sensors 174, 177, and 179 also in communication with the controller 120 to detect an overflow or trouble condition, respectively. For example, sensor 174 may be a water level sensor for detecting an accumulation of overflow water in the overflow catchment 172;

the sensors 177, 179 may be water flow sensors for detecting the presence of overflow water flowing through the drain line 176 and/or through the overflow line 178, respectively. In response to a detected overflow or trouble condition in the water collection module 170, the controller 120 can close the flow metering valve 112 on the injection line 130 and/or deactivate the pump 110, and/or alert an operator to a problem via the user interface 128.

[0028] Operation of the system is controlled by the controller 120, which as mentioned above is in operative communication with various sensors fitted to the system as well as to the actuator of the flow metering valve 112, the pump 110, and the engine 10. As illustrated in FIG. 2, the controller 120 includes a microcontroller or microprocessor system 122, and a number of interfaces that transmit and/or receive signals from other components of the system in response to instructions from the microcontroller. Thus, the controller 120 includes a pump control interface 124 that transmits signals to the pump 110 to control the pump's operation; a valve control interface 125 that transmits signals to the flow metering valve 112; and one or more sensor interfaces 127 that communicate with the various pressure, water level, etc. sensors provided in the system. The controller 120 also includes an engine interface 126 with the control system of the engine 10 to receive current operating status information, as well as a user interface 128 for signalling an operator of the system. The user interface 128 can include a graphic or LED display to indicate the status of various components and sensors of the system, as well as the engine 10; current operating capacity of the system; and warnings as required. The user interface 128 can also include an audio interface (e.g., speaker or audible alarm) to alert the operator to overflow or trouble conditions. In response to a detected operating status of the engine 10 received by the engine interface 126, the controller 120 activates or deactivates the pump 110, and sets its operating load, and adjusts the flow rate of the tainted water by controlling the flow metering valve 112, and optionally based on feedback from one or more sensors such as the pressure sensor 132. On detection of a change in the system or engine status, the controller 120 further adjusts the operation of the system as required, for example by deactivating or reactivating the pump 110 or changing its operating load, or altering the state of the flow metering valve 112.

[0029] As mentioned above, in operation, the tainted water is pumped from the tank 50 to the injection line 130, and emitted as a fine spray by one or more fine spray nozzles 156 while the engine is in operation and exhaust is being vented through the exhaust stack 20. The tainted water flow rate is selected by the controller 120 based on the current operating load of the engine 10, and signals are transmitted to the flow metering valve 112 and to the pump 110 to control the flow rate of the tainted water from the tank 50 accordingly. The flow rate is adjusted as necessary by the controller 120 in response to detected changes in the operating status of the engine 10 or other components of the system. The flow rate of the tainted water is preferably selected by the controller to ensure that a maximum amount of the injected water is vaporized on exposure to the exhaust gases, while maintaining adequate safety margins. An appropriate flow rate will thus be dependent on the engine's exhaust output—namely, the temperature and mass flow rate of exhaust gas from the engine. The volume of tainted water may be vaporized per unit time (the "water disposal rate") by a given engine may be estimated mathematically from the engine's exhaust characteristic, given a model of the vaporization chamber 150 where vaporization takes place.

[0030] It is contemplated that the onboard water processing and disposal system, as with the marine vessel's engines, may operate substantially continuously. Thus, it is presumed that the vaporization chamber's operation can be approximated as a steady-flow process. As will be understood by those skilled in the art, the energy entering and leaving a steady-flow process may be expressed as

$$\left(\dot{Q}_{IN} + \dot{W}_{IN} + \sum_{IN} \dot{m}\left(h + \frac{v^2}{2} + gz\right)\right) - \left(\dot{Q}_{OUT} + \dot{W}_{OUT} + \sum_{OUT} \dot{m}\left(h + \frac{v^2}{2} + gz\right)\right) = \frac{\partial E_{system}}{\partial t} = 0$$

[0031] where $\dot{Q}_{IN}$ represents the rate at which heat is absorbed into the system from the surroundings and $\dot{Q}_{OUT}$ the rate of heat lost by the system to the surroundings; $\dot{W}_{IN}$ and $\dot{W}_{OUT}$ represent the work done on and by the system; $\dot{m}$ is mass flow rate; h is enthalpy of the mass flowing though the inlets and outlets of the system; $\frac{v^2}{2}$ is the energy in the system resulting from kinetic energy of the fluid flow and gz represents potential energy gained or lost by the system.

[0032] In a simple model of the vaporization chamber 150, certain assumptions may be made: for example, it may be assumed that the vaporization chamber 150 and the exhaust stack 20 are generally well-insulated; that no work is done within the vaporization chamber; that changes to the kinetic and potential energies of the exhaust gas and water are negligible; and that steady operating conditions exist in the vaporization chamber 150. Accordingly, the above equation may be reduced to:

$$\sum_{IN} \dot{m}\,h - \left(\dot{Q}_{OUT} + \sum_{OUT} \dot{m}h\right) = 0$$

In an adiabatic system, the rate of heat transferred from the exhaust gas and absorbed by the tainted water is $\dot{Q}_{exhaust,out} = \dot{Q}_{water,in}$, where

$$\dot{Q}_{exhaust,out} = \dot{m}_{exhaust}\left(h_{exhaust,out} - h_{exhaust,in}\right) = \dot{m}_{exhaust} C_{p_{exhaust}}\left(T_{exhaust,out} - T_{exhaust,in}\right)$$

$$\dot{Q}_{water,in} = \dot{m}_{water}\left(h_{water,out} - h_{water,in}\right)$$

[0033] where *exhaust,out* denotes a value for the exhaust gases exiting the system and *exhaust,in* for the exhaust gases entering the system; *water,in* and *water,out* denotes a value for the water entering the system and the water vapour exiting the system, respectively; h is enthalpy and T is temperature of the exhaust gases or the water entering or exiting the system, as the case may be; $\dot{m}_{exhaust}$ and $\dot{m}_{water}$ are the mass flow rates of the exhaust gases and water flowing through the system, respectively; and $C_{p_{exhaust}}$ is the specific heat of the exhaust gases in the system, taken at an average of $T_{exhaust,out} - T_{exhaust,in}$. If an efficiency of 80% is assumed as a safety factor (i.e., 80% of the heat of the input exhaust gas is absorbed by the injected water), then from the above equations, $0.8\,\dot{Q}_{exhaust,out} = \dot{Q}_{water,in}$, and:

$$\dot{m}_{water}\left(h_{water,out} - h_{water,in}\right) = 0.8\,\dot{m}_{exhaust} C_{p_{exhaust}}\left(T_{exhaust,in} - T_{exhaust,out}\right)$$

[0034] Based on this model and assumptions, a linear relationship can thus be derived between the specific enthalpy of the water vapour at the outlet of the vaporization chamber 150 and the mass flow rate of the exhaust gases at specified initial and final conditions in order to determine a required mass flow rate in the vaporization chamber 150 in order to vaporize a specific mass flow rate of water. Calculations were made using the following initial and final properties of the exhaust gases and water to determine the relationship between the mass flow rate of exhaust into the vaporization chamber 150 and the rate at which tainted water may be disposed, i.e., the volumetric flow rate of water into the chamber 150:

Exhaust Gas Properties			
Property	**Units**	**Value**	**Explanation**
$T_{exhaust,in}$	°C	*varies*	Varies according to engine and operating conditions.
$P_{exhaust,in}$, $P_{exhaust,out}$	kPa	101.33	Pressure of exhaust gases throughout assumed to be atmospheric.
$\frac{\partial V_{exhaust,in}}{\partial t}$	m^3/s	*varies*	Volumetric flow rate of exhaust gases; varies according to engine and operating conditions
$\rho_{exhaust,in}$, $\rho_{exhaust,out}$	kg/m^3	0.63	Density of exhaust gases (assumed to be air)
$\dot{m}_{exhaust}$	kg/s	*varies*	Varies with volumetric flow rate and density.
$h_{exhaust,in}$	kJ/kg	567.06	Specific enthalpy at specified temperature and pressure†
$T_{exhaust,out}$	°C	127	Selected target temperature of exhaust gases exiting vaporization chamber
$C_{p_{exhaust}}$	kJ/kgK	1.03	Specific heat of air at atmospheric pressure, at average of temperatures at inlet and outlet of vaporization chamber
Water Properties			
Property	**Units**	**Value**	**Explanation**
$T_{water,in}$	°C	5	Selected example input temperature
$P_{water,in}$, $P_{water,out}$	kPa	101.33	Pressure throughout system assumed to be atmospheric; note that selection of pressure will have little effect on water density
$\frac{\partial V_{water,in}}{\partial t}$	m^3/s	0.03	Selected target volumetric flow rate of input water set at 20L/min
$\rho_{water,in}$	kg/m^3	1000.00	Density of water at atmospheric pressure
$\dot{m}_{water}$	kg/s	0.33	Derived from the volumetric flow rate and density
$h_{water,in}$	kJ/kg	293.01	Specific enthalpy of liquid water at specified temperature and pressure†
$h_{water,out}$	kJ/kg	2640.00	Specific enthalpy to vaporize 100% of water at given pressure

Table 1. Thermodynamic Properties Used in Calculations.

† Cengel, Yunus A. and Boles, Michael A. Thermodynamics: An Engineering Approach, Fifth Edition. Boston: McGraw Hill Custom Publishing, 2006.

[0035] A set of results illustrating the relationship between the water disposal rate (i.e., the volumetric flow rate of water) and the mass flow rate of exhaust gases into the modelled vaporization chamber 150 at a range of temperatures are set out in FIG. 3. The exhaust gas temperatures used in FIG. 3 are selected from a range of likely engine exhaust temperatures. As can be seen from FIG. 3, the target water disposal rate based on this model can be achieved for a range of exhaust temperatures, provided the exhaust mass flow rate is at least about 4.2 kg/s. As a point of reference, the MaK™ M43C 6-cylinder, 6000 kW engine was determined to have an exhaust mass flow rate of about 11.37 kg/s when running at full load.

[0036] To evaluate the effect of exhaust gas properties and the operating conditions of the engine on the vaporization of tainted water in this system, exhaust mass flow data was collected from engine manufacturers over a range of operating parameters (expressed as a percentage of maximum continuous rating (MCR)). FIG. 4 sets out exhaust mass flow data collected from a set of Wartsila™ engine models, as indicated in the table of FIG. 4. FIG. 5 sets out exhaust mass flow data collected from a set of MaK™ engine models, as indicated in the table of FIG. 5. It may be noted that as mass flow rate of the exhaust increases, the temperature decreases somewhat; however, the average temperature remains well above the water boiling point.

[0037] Consistent with the example system illustrated in FIG. 1, it was presumed that would be located such that the entirety of the exhaust gas flow in the stack 20 would be directed through the vaporization chamber 150. Based on this assumption, the relationship between the vaporization capacity ($\dot{m}_{water}$) or water disposal rate and engine load for the fourteen engines listed in the foregoing tables as well as two additional engines was computed using

$$\dot{m}_{water} = \frac{0.8\dot{m}_{exhaust}C_{p_{exhaust}}(T_{exhaust,in} - T_{exhaust,out})}{h_{water,out} - h_{water,in}}$$

[0038] in accordance with the equations given above. As can be seen from FIG. 6, based on the foregoing model and values, a number of heavy marine engines are capable of supporting water disposal rates well in excess of the target rate of 20L/min. For instance, based on performance data for a 8000 kW MaK™ 8M43C engine, the mass flow rate of exhaust gas in the vaporization chamber 152 can range from about 30000 kg/h (± 500 kg/min or ± 8.3 kg/s) at 50% load to a maximum of about 54000 kg/h (±900 kg/min or ± 15 kg/s) at 100% load. The temperature of the hot exhaust gas generated by the subject engine ranges from 328°C to 310°C. (See, for instance, the data overview in the MaK™ project guide (Appendix, pages 91-92) for the above-noted engine model, available at www.cat.com/engines/marine). With such a high exhaust flow rate, the produced exhaust gases are capable of carrying the sprayed water at most anticipated water disposal rates out of the engine exhaust, regardless of actual exhaust temperature.

[0039] It should be noted that these rates were computed based on all of the exhaust gas passing through the vaporization chamber 150. In some implementations, it may be desirable to divert a portion of the exhaust gas to the vaporization chamber 150 and the rest directly to the stack outlet 24 to minimize any back pressure caused by the vaporization process. It can be seen from the foregoing equations that the vaporization capacity of the system is directly proportional to the exhaust mass flow; thus, for example, in a system where 50% of the exhaust is being used for vaporization, the vaporization capacity can be determined by dividing the vaporization capacity for 100% of the exhaust in half. Even with this safety factor, which may not be necessary, it can be seen that a number of the sampled engines will still be capable of vaporizing the tainted water at the target rate. It should be recalled that the target rate is only a selected desired rate. Further, it should also be noted that the tainted water, in the example systems discussed above, will be sprayed in a fine spray into the vaporization chamber 150, thus increasing the ratio of surface area to volume of the tainted water droplets as compared to larger water droplets or a continuous stream of tainted water released into the chamber 150. Furthermore, the expected dwell time of the water droplets in the chamber 150, even if not vaporized, is expected to be only a few seconds until it is carried out of the stack by the flow of exhaust gases.

[0040] From the above analysis a simple relationship between engine power and vaporization capacity may be approximated in order to facilitate the establishment of operational thresholds of the onboard water processing and disposal system based on the vessel's engine. A proposed table for selecting an appropriate engine model based on target water disposal rates and the foregoing model is set out below:

Model Number	Vaporization Requirements (tonnes/day)	Minimum Required Engine Power (kW)
1	1-4	1100
2	5-8	2305
3	9-12	3520
4	13-15	4430

Table 2. Selection Criteria for use in Selecting an Engine Model.

[0041] Thus, where vaporization of 5-6 tonnes of tainted water/day by the system is desired, an engine having a minimum power of about 2305 kW would be selected. It should be noted that this table assumes that the engine is running at least at 75% of its rated capacity nonstop throughout the day, and includes a safety factor of about 4 to compensate for unknown variables such as inlet air temperature at the engine, the temperature of the tainted water to be processed, variabilities in engine load and exhaust properties, and heat loss by the system to the surroundings. For reference, a cargo vessel having 20-30 crew members with about 375 L of tainted water produced per crew member each day, would require daily disposal of about 7500-11250 litres or 7.5-11.25 tonnes of water. Cargo vessels with a large crew of 50 would require a daily disposal quantity of about 18.75 tonnes. These estimates require continuous water disposal rates of 5.2 to 13 L/min in order to process the water as it is produced each day.

[0042] It may be noted that the foregoing table relates to a single engine; a vessel having multiple engines may be equipped with a multiplex water processing and disposal system, as described with reference to FIG. 7 below. Once the maximum vaporization capacity is established for a given engine, the necessary specifications for the pump 110 and fine spray nozzles 156, as well as other components of the system, can be established. In some implementations, a non-variable speed pump 110 is utilized; thus the only factor varying the flow rate in the injection line 130 to the injector 154 is the flow metering valve 112. The size fine spray nozzles 156 may be selected according to the expected pressure in the injection line 130.

[0043] It will further be appreciated by those skilled in the art from the foregoing, and particularly the graph of FIG. 6, that for a given engine used with the water processing and disposal system, an appropriate flow rate of tainted water in the injection line 130 can be selected according to current, real-time characteristics of the exhaust gas emitted by the engine (the exhaust temperature, and principally the measured exhaust mass flow). Alternatively, based on previously known relationships between exhaust characteristics and engine load, the flow rate can be selected according to the current operating load of the engine. A rate card may thus be developed for a given engine to identify a target flow rate or pressure in injection line 130 in response to the measured mass flow of the exhaust, or in response to a detected status of the engine (e.g., throttle position or another indicator of the current operating load). For instance, a hypothetical rate card may be stored in memory of the controller 120, associating a set or range of current engine loads with maximum tainted water flow rates or corresponding flow metering valve positions, and optionally additional data as set out below:

Engine Model No. 1			
Current Load (%)	**Maximum Water Disposal Rate (L/min)**	**Maximum Water Flow Rate (L/min)**	**Valve Position**
100	56	42	1 [fully open]
75	35	26.25	0.60
50	20	15	0.34
25	0	0	0 [off]

Table 3. Example Rate Card.

[0044] The rate card can also include other data available from the engine manufacturer, such as power ratings at various loads, the exhaust gas mass flow, and exhaust temperature.

[0045] Thus, when the controller 120 determines via the engine interface 126 that the engine load (e.g., throttle position) is at its maximum rating, the maximum water flow rating is 42 L/min, and the flow metering valve may be fully open, whereas when the load is below 25% of full capacity no tainted water is delivered to the injection line 130. The rate card can also include additional information such as the operating load of the pump 110, which together with the position of the flow metering valve can determine the flow rate of tainted water in the injection line 130. As long as the detected status of the engine 10 indicates that the engine load meets or exceeds a specified load, the controller 120 operates the pump 110 and flow metering valve 112 to deliver up to the maximum tainted water flow rate to the fine spray nozzle 156.

[0046] In this manner, the controller 120 controls the pump 110, flow metering valve 112, and controls or monitors other components so as to ensure that the water flow from the tank 50 to the water injector 154, as determined by the operating load of the pump 110 and the state of the valve 112, is synchronized with the current maximum vaporization capacity (based on the current mass flow of exhaust gas) and/or current operating load of the engine 10. The controller 120 further monitors or controls the rate of water supply from the tank 50 to the water injector 154 to ensure that overflow conditions are avoided or minimized. Thus, in addition to the safety margins that may be incorporated into the rate card values discussed above, the onboard water treatment and disposal system can include a number of additional sensors or safety mechanisms to maintain system operation within safe parameters.

[0047] As noted above, a flow meter 158 may be positioned in the engine stack 20 proximate to or within the shaft 152 of the vaporization chamber 150 to detect a state of the engine status. Locating flow meter 158 upstream from the vaporization chamber 150 (i.e., between the engine 10 and the vaporization chamber 150) can provide advance notice of changes to the exhaust flow detected in the stack 20 caused by a fault in the exhaust stack 20, such as a blockage, leak, or other failure. The flow meter 158 also provides an additional indication of engine status (i.e., whether the engine is off, or operating at full or partial capacity). The detected flow rate is transmitted by the meter 158 to the controller 120, which can use the received data and the rate card or other stored data for the engine to determine a likely current operational load of the engine 10. Thus, the readings from the meter 158 can provide redundancy for engine status data received directly from the engine 10 by the engine interface 126.

[0048] Rather than a flow meter 158, the sensor in the exhaust stack 20 may instead be, or include, a pressure sensor and/or or temperature sensor. However, use of other variables such as temperature may not provide a straightforward indication of engine status; for example, for some engines the exhaust temperature may actually drop at higher power outputs when the mass flow rate of the exhaust gas increases. The exhaust temperature may also be influenced by external factors.

[0049] The injection line includes a pressure sensor or flow meter 132, which provides an estimated delivery rate of tainted water through the injection line 130 and the fine spray nozzle 156. The fine spray nozzle 156 is generally selected to supply a metered flow rate based on a predetermined pressure level; accordingly, the controller 120 can use readings from the pressure sensor 132 to adjust the flow rate of the tainted water through the injection line 130 to meet the predetermined pressure level.

[0050] The sensors 104, 174, 177, and 179, as discussed above, provide indications of overflow or water level conditions in the tainted water supply and water collection module 170, and are used by the controller 120 to determine whether overflow or other trouble conditions exist and take corrective action as required.

[0051] The controller 120 is further configured to deactivate the pump 110 in response to a number of conditions. Primarily, the controller 120 deactivates the pump 110 when there is an indication from either the engine 10 or the sensor 158 that the engine operating load is too low to process the supply of tainted water, or if any of the other readings from the other sensors in the system, or the engine status, indicates a condition that is out of bounds, such as a pressure level in injection line 130 that is above the predetermined pressure level or another specified limit. The controller 120 may also be configured to shut down the pump 110 in the event the pressure reading from the sensor 132 is below a threshold less than the predetermined pressure level, as this may indicate a faulty pump, sensor 158, or a fault in one of the delivery or injection lines or the fine spray nozzle(s) 156.

[0052] Additionally, the controller 120 can be further configured to initiate the water treatment and disposal system only when certain safety conditions are met, such as confirmation (via the engine interface 126 and the various system sensors) that the engine meets a minimum operating level and a minimum flow rate of exhaust gas is present in the exhaust stack 20. In the case of motive power engines such as those set out in the tables above, there will typically be sufficient exhaust gas flow to prevent overflow water from collecting in the water collection module 170; however, this may not be the case for smaller auxiliary engines, so confirming the mass flow rate of the exhaust in each stack used for tainted water processing is recommended.

[0053] An additional safety condition to be verified by the controller 120 is the model or configuration of the engine 10 to verify that it is capable of vaporizing a given volume of tainted water at a specified engine load. Depending on the detected model or capacity of the engine to vaporize water, which may be determined by a query to the engine's control system via the engine interface 126, operator input, or by sampling the exhaust flow rate in the exhaust stack 20, the controller 120 can select a range of flow rates that the particular engine 10 will be able to process.

[0054] In further variations of the onboard water processing and disposal system, the water injector 154 may include a plurality of fine spray nozzles 156, rather than a single fine spray nozzle. Another possible variation of the onboard water processing and disposal system is illustrated in FIG. 7. In this example, the marine vessel is outfitted with more than one engine 10a, 10b, 10c, etc., each being connected to at least one exhaust stack of the vessel. For ease of description, FIG. 7 illustrates only one example exhaust stack 20 connected to a first engine 10a.

[0055] In this example, the tainted water supply (e.g., tank 50, pump 110, and the safety valves and other intermediate components) are substantially similar to the supply configuration of FIG. 1. The pump 110 then directs the flow of tainted water through line 130 to a manifold 135 connected to a plurality of injection lines 137a, 137b, 137c, etc., corresponding to each of the exhaust stacks of the engines on the vessel. Each injection line is thus equipped with its own flow metering valve 112a, 112b, 112c, and pressure sensors 132a, 132b, 132c, which are in communication with the controller 120 as generally described above. The outlet of each injection line 137a, 137b, 137c is connected to a corresponding water injector 154 positioned in a shaft 152 of the corresponding vaporization chamber 150 for the corresponding engine stack 20 of a particular engine 10a, 10b, or 10c; each water injector 154 includes one or more fine spray nozzles 156 as described above.

[0056] The controller 120 thus controls the flow of tainted water from the single tank 50 to one or more of the multiple injection lines 137a, 137b, 137c in dependence on the current operating status of the corresponding engine 10a, 10b, 10c, again as discussed above. The water collection module 150 for each engine stack 20 is similar to that described above with reference to FIG. 1, although multiple water collection modules 150 would be installed for each exhaust stack 20 on the vessel integrated into the system.

[0057] In any of the above embodiments, the storage tank 50 may be used to temporarily store water during peak production periods such as shift changes, and hold the water for disposal until the system is able to process the water during low production periods, such as overnight. The system may safely dispose of the tainted water whenever the engine 10 is operating above some minimum engine operating level. In one implementation, the minimum engine operating level is selected to be a rate at which the anticipated daily water consumption can be safely disposed of over a 24-hour period. In this fashion, the system would operate continuously, or nearly continuously, even when the vessel is operating at manoeuvring speeds lower than the maximum cruise speed.

[0058] Accordingly, it will be appreciated by those skilled in the art that the foregoing description provides a simple solution to tainted water processing and disposal onboard a marine vessel that is easily integrated into conventional engine stack configurations, does not require complex heat exchanger arrangements, or even transfer of heat away from the engine stack 20 in order to effectively dispose of unwanted water away from port or shoreside water disposal facility, and without requiring overboard discharge.

[0059] In the system described above, the high temperature and mass flow of the exhaust gases in the engine stack 20 is sufficient to vaporize the injected tainted water so as to reduce the volume of water that needs to be discharged overboard or otherwise. The exhaust temperatures to which the tainted water is exposed in the stream of exhaust gases may be sufficiently high to kill or neutralize bacteria in the tainted water. Concerns about back pressure in the exhaust stack may be mitigated, as compared to prior art solutions, by the fine diameter of the tainted water spray.

[0060] Further, because the mass flow of the gas effectively governs the water disposal rate and can be reliably correlated to engine performance, it is possible to construct the processing and disposal system to easily select appropriate water flow rates to the injectors 154. By synchronizing the flow rates of the tainted water into the exhaust stack to the engine load (e.g., throttle position, or other indicator or the current engine load), the tainted water processing and disposal system can be operated substantially continuously at varying flow rates as long as the engine is operating. It is not necessary to monitor other engine operational characteristics, such as exhaust temperature, in order to determine the flow rate of tainted water to be delivered to the injectors 154. Exhaust temperature may be monitored simply as an optional safety mechanism, e.g. a failsafe that triggers the controller to shut down operation of the system in the event temperature drops below a minimum threshold.

[0061] In addition, as noted above, the holding tank 50 can capture tainted water from various sources such as sewage water, oily water, wash water, and so forth. As those skilled in the art appreciate, some amount of oil or other contaminants may remain in water processed onboard other systems on the vessel, and these contaminants may still be present in concentrations above those permitted for disposal by regulation. However, by mixing these different waters in the holding tank 50, the concentration of contaminants in any tainted water that is not vaporized in the vaporization chamber 150 will be diluted. Furthermore, the system includes a strainer 107 so that certain types of waste water, such as bilge water, that are typically unfiltered prior to disposal are now also filtered, thus reducing the amount of sediment and particulate released into the environment.

[0062] The examples and embodiments are presented above only by way of example and are not meant to limit the scope of the subject matter described herein. Variations of these examples and embodiments will be apparent to those skilled in the art, and are considered to be within the scope of the subject matter described herein. For example, it will be recognized by those skilled in the art that the systems and methods may be implemented on other marine structures, such as oil rigs, although the primary engine or generator may not be used for motive power. Some steps or acts in a process or method may be reordered or omitted, and features and aspects described in respect of one embodiment may be incorporated into other described embodiments.

[0063] The data employed by the controller described herein may be stored in one or more data stores. The data stores can be of many different types of storage devices and programming constructs, such as RAM, ROM, flash memory, programming data structures, programming variables, and so forth. Code adapted to provide the systems and methods described above may be provided on many different types of computer-readable media including computer storage mechanisms that contain instructions for use in execution by one or more processors to perform the operations described herein. The media on which the code and data may be provided is generally considered to be non-transitory or physical. Functional units of the controller need not be physically located together, but may reside in different locations, such as over several electronic devices or memory devices, capable of being logically joined for execution. Functional units may also be implemented as combinations of software and hardware, such as a processor operating on a set of operational data or instructions.

[0064] Throughout the specification, terms such as "may" and "can" are used. Use of any particular term should not be construed as limiting the scope or requiring experimentation to implement the claimed subject matter or embodiments described herein. Any suggestion of substitutability of the data processing systems or environments for other implementation means should not be construed as an admission that the invention(s) described herein are abstract, or that the hardware components are non-essential to the invention(s) described herein. Further, while this disclosure may have articulated specific technical problems that are addressed by the invention(s), the disclosure is not intended to be limiting in this regard; the person of ordinary skill in the art will readily recognize other technical problems addressed by, and technical benefits provided, by the invention(s).

Claims

1. A water processing system for use on a marine vessel equipped with at least one engine and a corresponding at least one exhaust assembly, the water processing system comprising:

a tainted water source;

a pump in fluid communication with the tainted water source;

at least one fine spray nozzle in fluid communication with the pump, the at least one fine spray nozzle being positioned to direct a spray of the tainted water into one of the at least one exhaust assembly;

a controller configured to:

receive an indication of the current operating load of the engine corresponding to the exhaust assembly;

select a flow rate for the tainted water from a plurality of predefined flow rates defined for a corresponding plurality of engine operating loads; and

control the flow of the tainted water according to the selected flow rate from the tainted water source to the at least one fine spray nozzle.

2. The water processing system of claim 1, wherein the controller controls a valve regulating the flow of the tainted water from the tainted water source to the at least one fine spray nozzle.

3. The water processing system of claim 2, wherein the indication of the current operating load excludes a temperature reading of the corresponding exhaust assembly.

4. The water processing system of any one of claims 1 to 3, wherein the plurality of predefined flow rates correspond to a plurality of incremental operating loads of the corresponding engine.

5. The water processing system of claims 1 to 4, wherein the plurality of flow rates are predetermined based on a previous evaluation of a temperature and mass flow rate of exhaust gases produced by the corresponding engine at one or more selected operating loads.

6. The water processing system of any one of claims 1 to 5, wherein the controller is further configured to activate the pump when the indication indicates that current operating load of the corresponding engine meets or exceeds a minimum operating load.

7. The water processing system of claim 6, wherein the controller is further configured to deactivate the pump when the indication indicates that current operating load of the corresponding engine is below a minimum operating load.

8. The water processing system of any one of claims 1 to 7, wherein the indication of the current operating load comprises an indication of an engine throttle position.

9. The water processing system of any one of claims 1 to 8, wherein droplet diameters of the spray of the tainted water range from about 25 μm to about 400 μm.

10. The water processing system of any one of claims 1 to 9, wherein the tainted water source comprises a collection tank receiving tainted water drawn from at least one of multiple sources on the marine vessel.

11. The water processing system of claim 10, wherein the multiple sources include one or more of a marine sanitation device, an oily water separation system, and a bilge of the marine vessel.

12. The water processing system of any one of claims 1 to 11, wherein the tainted water originates from sewage, bilge water, grey water, residual water from washing a cargo hold or the marine vessel, or a combination of two or more thereof.

13. The water processing system of any one of claims 1 to 12, wherein the at least one fine spray nozzle is positioned to direct the spray of the tainted water into the exhaust assembly below the exhaust stack of the exhaust assembly.

14. The water processing system of claim 13, wherein the at least one fine spray nozzle is positioned to direct the spray of the tainted water into the exhaust assembly between the exhaust stack of the exhaust assembly and above a water collector of the exhaust assembly.

15. The water processing system of any one of claims 1 to 14, comprising a plurality of fine spray nozzles.

16. The water processing system of any one of claims 1 to 15, wherein the marine vessel comprises a plurality of engines and a plurality of corresponding exhaust assemblies, and the water processing assembly further comprises:

at least one fine spray nozzle positioned to direct the spray of the tainted water into each exhaust assembly of the plurality of corresponding exhaust assemblies, each fine spray nozzle being in fluid communication with the pump and the tainted water source via a manifold,

the controller being configured to control a flow of the tainted water from the tainted water source to each of the at least one fine spray nozzle for each corresponding exhaust assembly, responsive to a detected current operating load of the engine corresponding to the exhaust assembly.

17. The water processing system of claim 16, wherein the controller controls a plurality of valves regulating the flow of the tainted water from the tainted water source to the at least one fine spray nozzle for the plurality of corresponding exhaust assemblies.

18. A water disposal system for use with at least one engine and a corresponding at least one exhaust stack, the water disposal system comprising:

a vaporization chamber comprised in an exhaust assembly, the vaporization chamber comprising at least one fine spray nozzle positioned to direct a spray of water into exhaust from the at least one engine corresponding to the exhaust assembly passing through the exhaust assembly;

a water source for holding water received from one or more water treatment systems;

a processing apparatus for delivering the water from the water source to the vaporization chamber;

a water collection apparatus comprised in the exhaust assembly positioned to receive and sequester overflow water sprayed into the exhaust assembly by the at least one fine spray nozzle that is expelled from the vaporization chamber in liquid form.

19. The water disposal system of claim 18, wherein the processing apparatus comprises:

at least one pump in fluid communication with the water source and the at least one fine spray nozzle;

at least one valve in fluid communication with the pump, regulating the flow of the water from the source to the at least one fine spray nozzle; and

a controller configured to operate the at least one valve to adjust a flow rate of the water to the at least one fine spray nozzle.

20. The water disposal system of claim 19, wherein the controller is configured to adjust the flow rate of the water responsive to a detected current state of the engine corresponding to the exhaust assembly, the current state being correlated to an estimated mass flow range and temperature range of exhaust emitted by the engine into the exhaust assembly.

21. The water disposal system of any one of claims 18 to 20, wherein the one or more water treatment systems comprise a marine sanitation device, an oily water separation system, or both a marine sanitation device and an oily water separation system, the water held in the water source thus having been treated by the one or more water treatment systems before being received in the water source.

22. The water disposal system of claim 21, further comprising at least one purge line for removal of water between the water source and the pump.

23. The water disposal system of either claim 21 or 22, wherein the processing apparatus further comprises a strainer between the water source and the pump.

24. The water disposal system of claim 23, further comprising a flush line in communication with the strainer.

25. The water disposal system of any one of claims 18 to 24, implemented on a marine vessel.

26. The water disposal system of claim 25, wherein the water collection apparatus comprises at least one bilge line.

27. A method of water disposal implemented on a marine vessel, the method comprising:

receiving tainted water from at least one tainted water source;

while an engine of the marine vessel is operating, regulating a flow of the tainted water to at least one fine spray nozzle in response to a detected current operating load of the engine, the at least one fine spray nozzle being positioned to direct a spray of the tainted water into an exhaust assembly corresponding to the engine; and

spraying the tainted water into engine exhaust gas in the exhaust assembly to thereby vaporize the tainted water.

28. The method of claim 27, wherein regulating the flow of the tainted water comprises:

receiving an indication of the current operating load of the engine;

selecting a flow rate for the tainted water based on the indication of the current operating load; and

adjusting the flow of the tainted water between the at least one tainted water source and the at least one fine spray nozzle up to about the selected flow rate.

29. The method of claim 28, wherein selecting the flow rate comprises selecting a flow rate from a set of flow rates, the flow rates of the set of flow rates corresponding to a set of operating loads of the engine.

30. The method of claim 29, wherein the set of flow rates are determined from temperatures and mass flow rates of exhaust gases produced by the engine at the set of operating loads.

31. The method of any one of claims 28 to 30, further comprising:

detecting a change in the operating load of the engine;

selecting a new flow rate for the tainted water based on the changed operating load; and

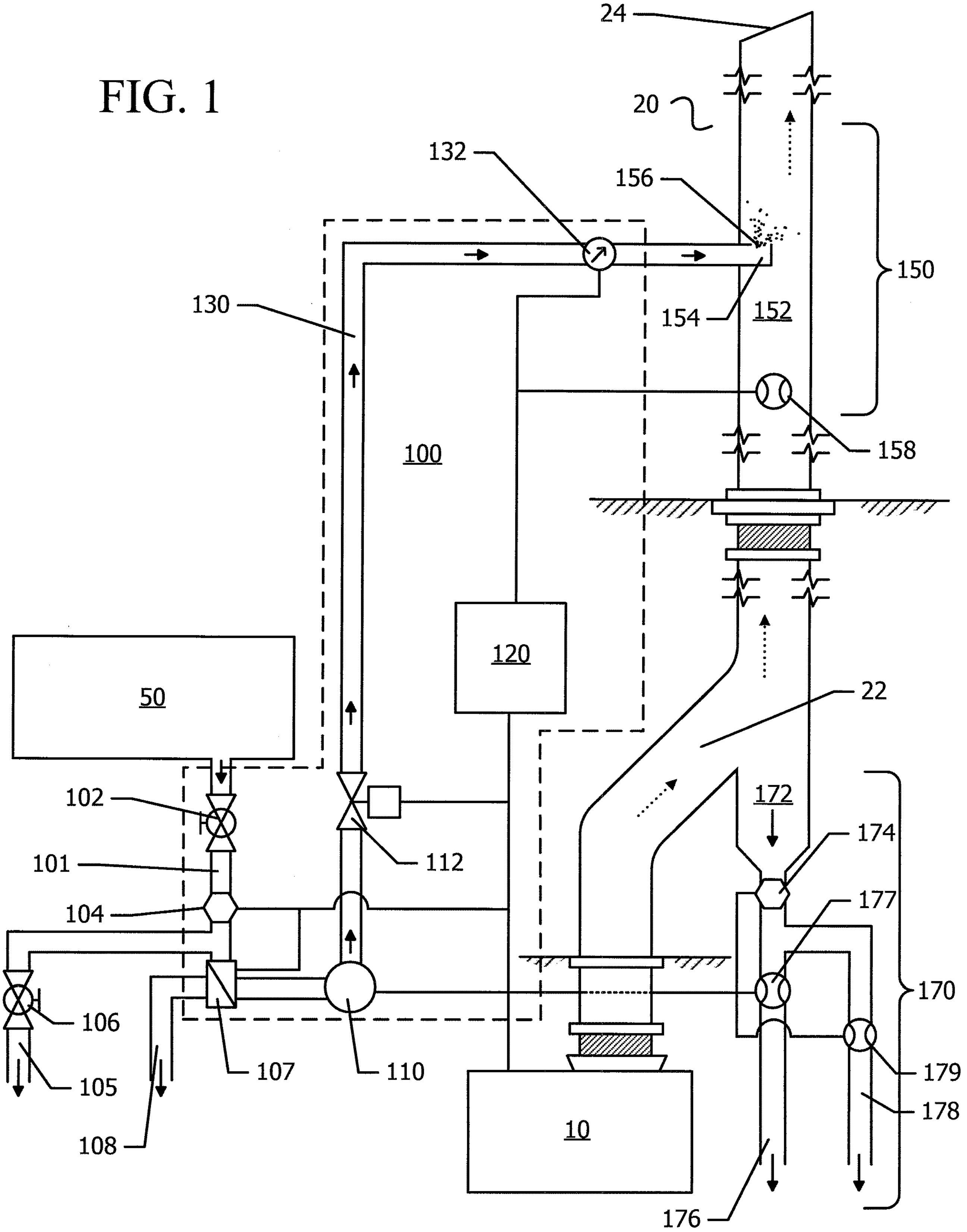
adjusting the flow of the tainted water between the at least one tainted water source and the at least one fine spray nozzle up to about the selected flow rate.

32. The method of any one of claims 27 to 31, further comprising catching falling overflow water sprayed into the exhaust assembly by the at least one fine spray nozzle.

33. The method of any one of claims 27 to 32, wherein the at least one tainted water source includes one or more of a marine sanitation device, an oily water separation system, and a bilge of the marine vessel.

34. The method of any one of claims 27 to 33, wherein the tainted water comprises water previously treated by the oily water separation system.

FIG. 1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20
132
156
150
130
154
152
158
100
120
50
22
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172
174
101
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10
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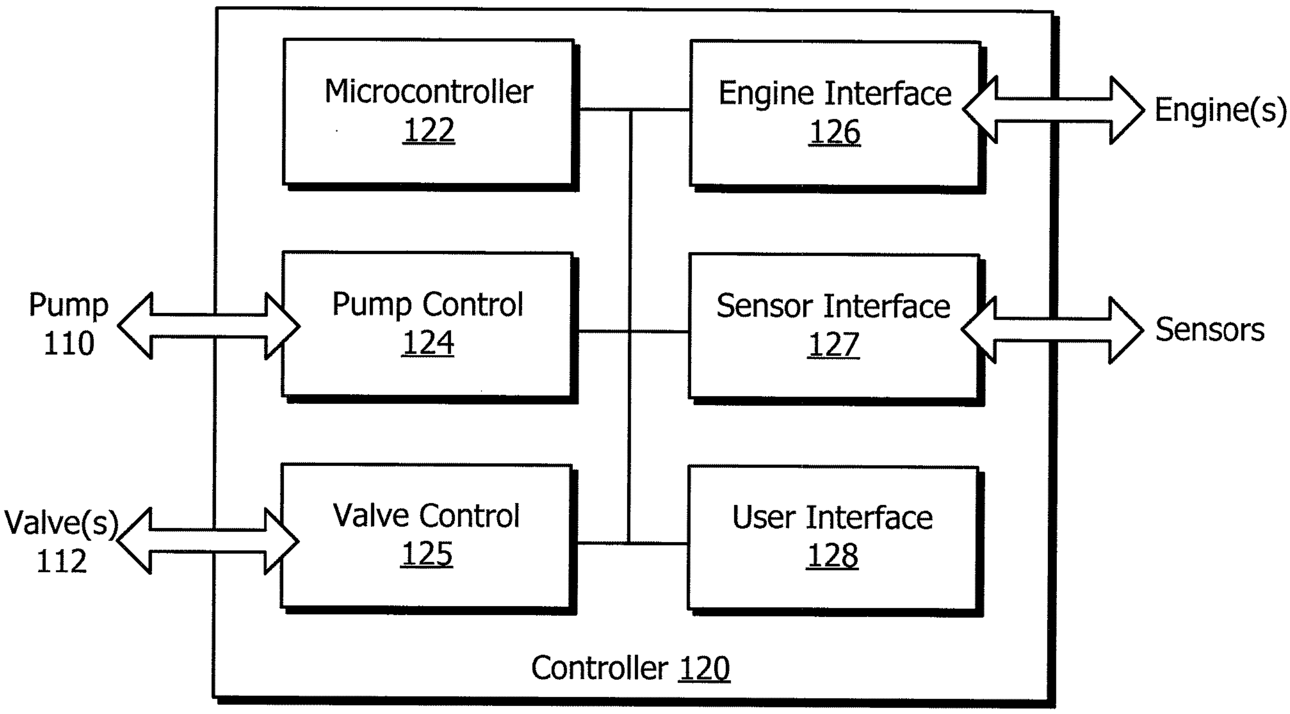
Microcontroller
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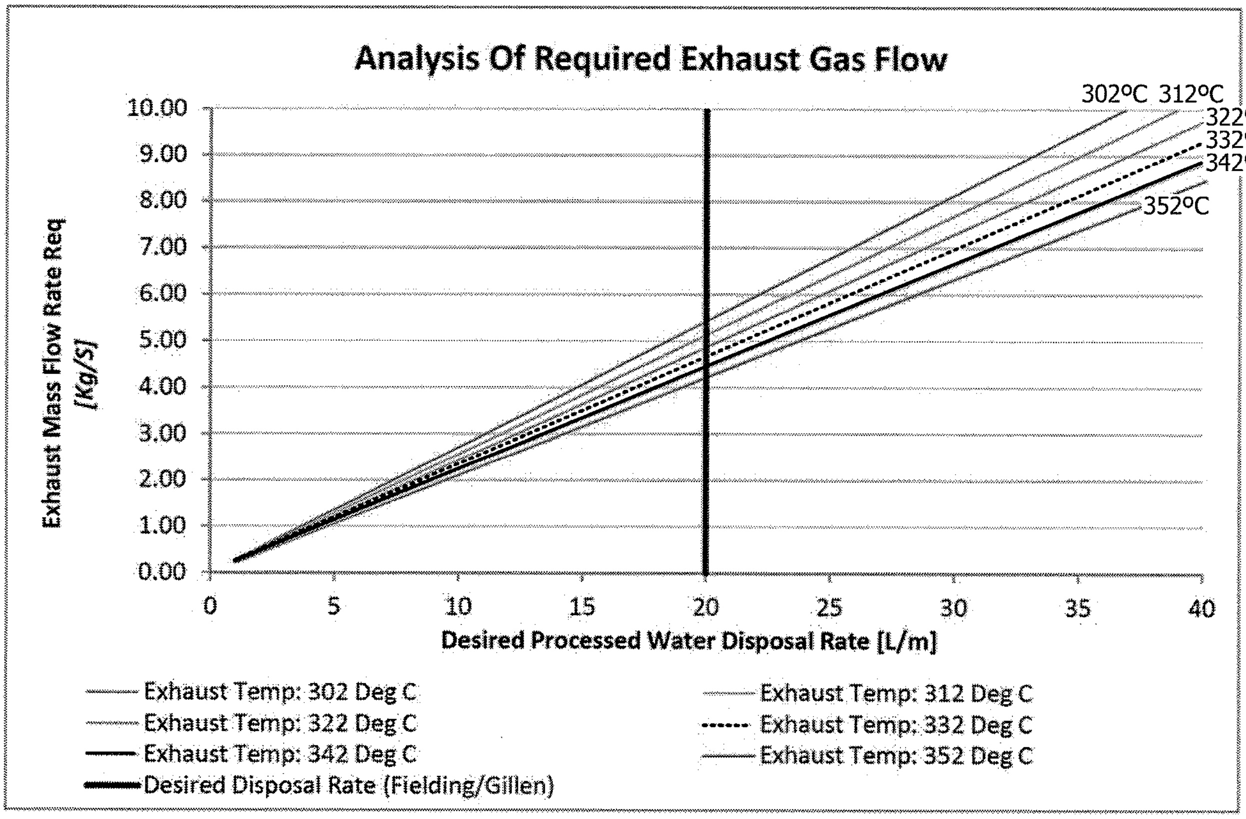
Engine Interface
126
Engine(s)
Pump
110
Pump Control
124
Sensor Interface
127
Sensors
Valve(s)
112
Valve Control
125
User Interface
128
Controller 120

FIG. 2



Analysis Of Required Exhaust Gas Flow
302°C 312°C
322°C
332°C
342°C
352°C
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Exhaust Mass Flow Rate Req [Kg/S]
0
5
10
15
20
25
30
35
40
Desired Processed Water Disposal Rate [L/m]
Exhaust Temp: 302 Deg C
Exhaust Temp: 312 Deg C
Exhaust Temp: 322 Deg C
Exhaust Temp: 332 Deg C
Exhaust Temp: 342 Deg C
Exhaust Temp: 352 Deg C
Desired Disposal Rate (Fielding/Gillen)

FIG. 3

	100% Load				85% Load				75% Load				50% Load			
Engine Model	$\dot{m}$ kg/s	T °C	C_p kJ/kgK	h_{in} kJ/kg	$\dot{m}$ kg/s	T °C	C_p kJ/kgK	h_{in} kJ/kg	$\dot{m}$ kg/s	T °C	C_p kJ/kgK	h_{in} kJ/kg	$\dot{m}$ kg/s	T °C	C_p kJ/kgK	h_{in} kJ/kg
4L20	1.55	370	1.06	654	1.39	340	1.055	621	1.20	350	1.058	632	0.80	385	1.066	670
6L26	4.20	312	1.05	591	3.50	313	1.049	592	3.10	327	1.052	607	2.30	322	1.051	602
6L32	6.75	360	1.06	643	5.92	335	1.054	616	5.16	355	1.059	637	4.05	340	1.055	621
6L38	7.85	389	1.06	674	7.25	320	1.051	600	6.31	328	1.052	608	4.92	314	1.049	593
9L38	11.78	389	1.07	674	10.88	320	1.051	600	9.46	328	1.052	608	7.39	314	1.049	593
7L46F	15.00	374	1.06	658	13.30	320	1.051	600	12.20	332	1.053	613	8.00	352	1.058	634
9L46F	19.30	374	1.06	658	17.10	320	1.051	600	15.70	332	1.053	613	10.3	352	1.058	634

FIG. 4

Engine Model	100% Load				75% Load				50% Load			
	$\dot{m}$ kg/s	T °C	C_p kJ/kgK	h_{in} kJ/kg	$\dot{m}$ kg/s	T °C	C_p kJ/kgK	h_{in} kJ/kg	$\dot{m}$ kg/s	T °C	C_p kJ/kgK	h_{in} kJ/kg
6M25C	4.11	327	1.052	608	3.11	340	1.055	622	2.09	377	1.064	661
6M20C	2.09	366	1.061	649	1.61	381	1.065	665	1.12	401	1.069	686
6M43C	11.29	310	1.048	590	8.87	304	1.047	584	6.25	328	1.052	609
6M32C	5.78	291	1.044	570	4.48	288	1.044	567	3.03	314	1.049	594
8M43C	15.05	310	1.048	590	11.83	304	1.047	584	8.33	328	1.052	609
9M43C	16.93	310	1.048	590	13.31	304	1.047	584	9.37	328	1.052	609
9M32C	8.66	291	1.044	570	6.73	288	1.044	570	4.54	314	1.044	570

Engine Model	25% Load				10% Load			
	$\dot{m}$ kg/s	T °C	C_p kJ/kgK	h_{in} kJ/kg	$\dot{m}$ kg/s	T °C	C_p kJ/kgK	h_{in} kJ/kg
6M25C	1.32	381	1.065	665	0.96	328	1.052	609
6M20C	0.70	399	1.069	684	0.47	340	1.055	622
6M43C	3.43	345	1.056	627	2.61	269	1.040	547
6M32C	1.73	334	1.054	616	1.16	262	1.038	540
8M43C	4.57	345	1.056	627	3.48	269	1.040	547
9M43C	5.14	345	1.056	627	3.91	269	1.040	547
9M32C	2.59	334	1.044	570	1.74	262	1.044	570

FIG. 5

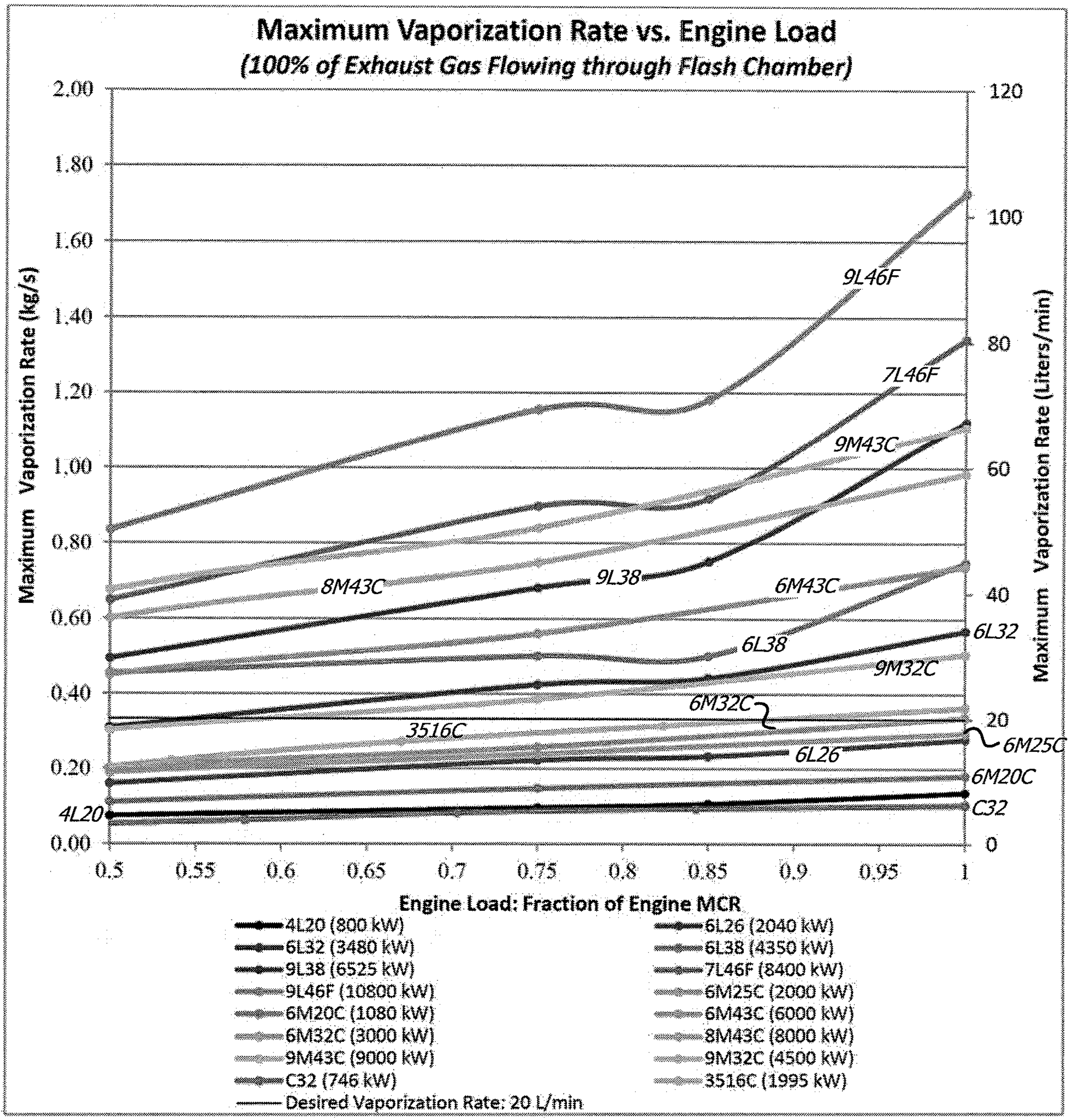
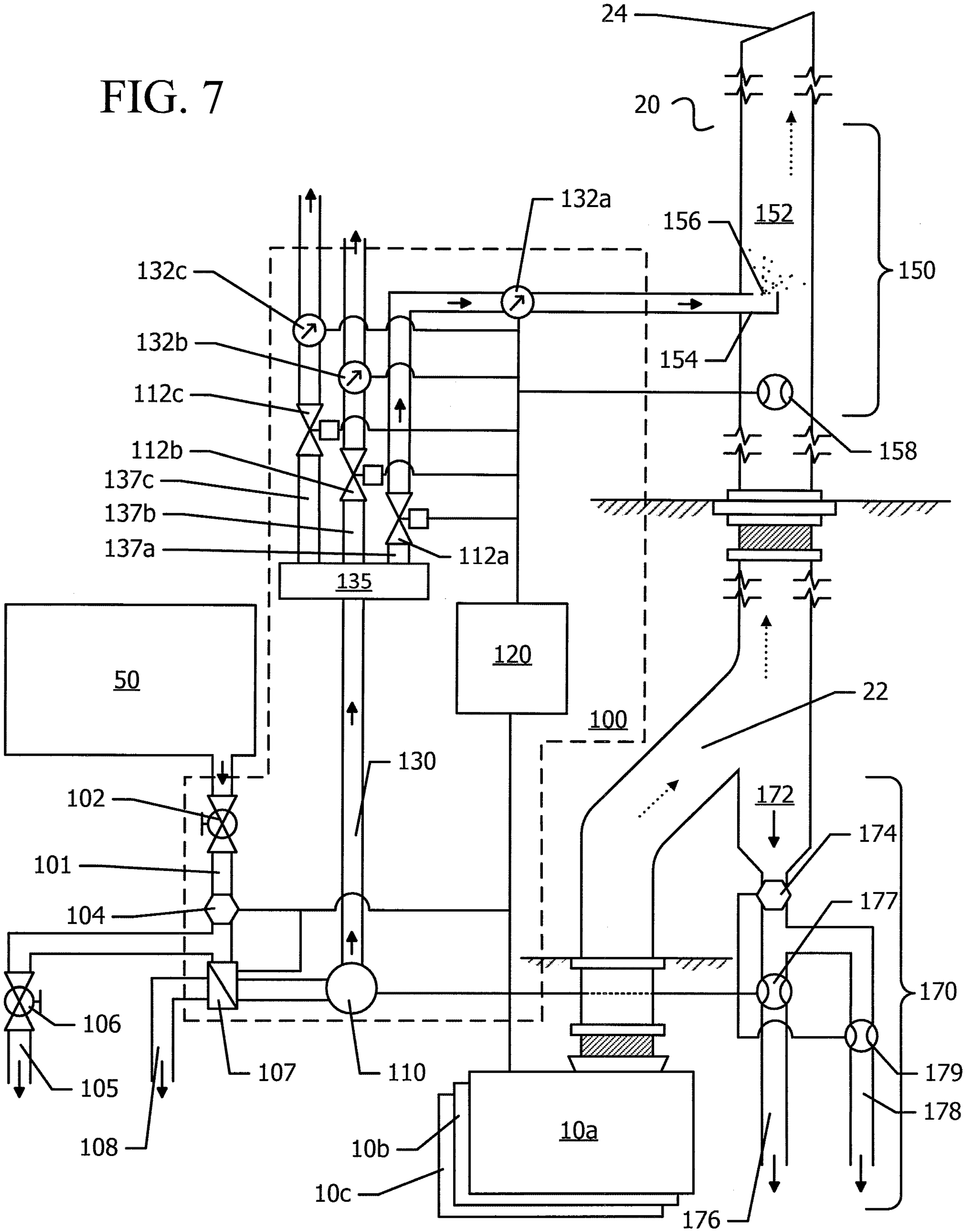

Maximum Vaporization Rate vs. Engine Load
(100% of Exhaust Gas Flowing through Flash Chamber)
Maximum Vaporization Rate (kg/s)
Maximum Vaporization Rate (Liters/min)
Engine Load: Fraction of Engine MCR
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
120
100
80
60
40
20
0
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
9L46F
7L46F
9M43C
8M43C
9L38
6M43C
6L38
6L32
9M32C
6M32C
3516C
6M25C
6L26
6M20C
4L20
C32
4L20 (800 kW)
6L26 (2040 kW)
6L32 (3480 kW)
6L38 (4350 kW)
9L38 (6525 kW)
7L46F (8400 kW)
9L46F (10800 kW)
6M25C (2000 kW)
6M20C (1080 kW)
6M43C (6000 kW)
6M32C (3000 kW)
8M43C (8000 kW)
9M43C (9000 kW)
9M32C (4500 kW)
C32 (746 kW)
3516C (1995 kW)
Desired Vaporization Rate: 20 L/min

FIG. 6

FIG. 7


24
20
152
156
132a
150
132c
132b
112c
112b
137c
137b
137a
154
158
112a
135
50
120
100
22
130
172
102
101
104
174
177
170
106
105
107
110
108
10a
10b
10c
179
178
176

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2016/050139

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***B63J 4/00*** (2006.01) , ***B63B 29/16*** (2006.01) , ***C02F 1/04*** (2006.01) , ***C02F 1/12*** (2006.01)

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)
IPC: ***B63J 4/00*** (2006.01) , ***B63B 29/16*** (2006.01) , ***C02F 1/04*** (2006.01) , ***C02F 1/12*** (2006.01) , ***C02F 1/16*** (2006.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Database: FAMPAT (Questel Orbit)
Keywords: Water, treat+, spray, exhaust, bilge, sewage, nozzle, waste, tainted, marine, ship, vapo?ri+, and similar terms or combinations thereof.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	CA 1060334 A (WATERS, C.H. et al.) 14 August 1979 (14-08-1979) * whole document, particularly: Fig. 1 & 2a; page 1, lines 1-5; page 9, line 22 to page 10, line 5; page 10, line 27 to page 13, line 21; and claims 8, 11, and 16 *	1-13, 15-17, 27-31, 33, & 34 9, 14, 18-26, & 32
Y	US 3,933,636 A (DANIELS, R.A.) 20 January 1976 (20-01-1976) * whole document, particularly: Fig. 1 & 2; column 10, lines 11-14 *	1-34
Y	WO 2009/043135 A1 (FIELDING, I. et al.) 9 April 2009 (09-04-2009) * whole document, particularly: Fig. 4a & 5a *	14, 18-26, & 32
Y	US 6,106,703 A (NASSEF, N.A.) 22 August 2000 (22-08-2000) * whole document *	1-34
Y	US 3,635,276 A (GREEN, H.W. et al.) 18 January 1972 (18-01-1972) * whole document *	1-34

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

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier application or patent but published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
25 October 2016 (25-10-2016)

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28 October 2016 (28-10-2016)

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,633,746 A (DIETERICH, M.L.) 11 January 1972 (11-01-1972) * whole document *	1-34
A	CN 104828240 A (ZHANG, R.) 12 August 2015 (12-08-2015) * whole document *	
A	CN 204356123 U (ZHANG, R.) 27 May 2015 (27-05-2015) * whole document *	
A	WO 2005/090151 A1 (SIVERTSSON, H.) 29 September 2005 (29-09-2005) * whole document *	

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
CA1060334A	14 August 1979 (14-08-1979)	CH619431A5 DE2555118A1 DK553975A ES443322A1 ES451460A1 FI753360A FI63706B FI63706C FR2293961A1 FR2293961B1 GB1491587A IL48626D0 IL48626A IT1052538B JPS5196161A NL7513908A NO754127A SE7513488L US4018683A US4066545A	30 September 1980 (30-09-1980) 24 June 1976 (24-06-1976) 10 June 1976 (10-06-1976) 16 September 1977 (16-09-1977) 01 October 1977 (01-10-1977) 10 June 1976 (10-06-1976) 29 April 1983 (29-04-1983) 10 August 1983 (10-08-1983) 09 July 1976 (09-07-1976) 23 July 1982 (23-07-1982) 09 November 1977 (09-11-1977) 29 February 1976 (29-02-1976) 31 October 1978 (31-10-1978) 20 July 1981 (20-07-1981) 23 August 1976 (23-08-1976) 11 June 1976 (11-06-1976) 10 June 1976 (10-06-1976) 10 June 1976 (10-06-1976) 19 April 1977 (19-04-1977) 03 January 1978 (03-01-1978)
US3933636A	20 January 1976 (20-01-1976)	JPS51127582A	06 November 1976 (06-11-1976)
WO2009043135A1	09 April 2009 (09-04-2009)	None	
US6106703A	22 August 2000 (22-08-2000)	None	
US3635276A	18 January 1972 (18-01-1972)	None	
US3633746A	11 January 1972 (11-01-1972)	CA922853A DE2039218A1 FR2056694A5 GB1298389A GB1298390A	20 March 1973 (20-03-1973) 04 March 1971 (04-03-1971) 14 May 1971 (14-05-1971) 29 November 1972 (29-11-1972) 29 November 1972 (29-11-1972)
CN104828240A	12 August 2015 (12-08-2015)	None	
CN204356123U	27 May 2015 (27-05-2015)	None	
WO2005090151A1	29 September 2005 (29-09-2005)	EP1727730A1 SE0400755D0 SE0400755A SE526811C2	06 December 2006 (06-12-2006) 22 March 2004 (22-03-2004) 23 September 2005 (23-09-2005) 08 November 2005 (08-11-2005)