

A SYSTEM AND METHOD FOR MEASURING THE AMOUNT OF FUEL
DELIVERED IN A BUNKERING OPERATION

FIELD OF THE INVENTION

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The present disclosure relates to a system for measuring the amount of bunker fuel delivered in a bunkering operation for a large ocean going ship with a vibrating meter, such as e.g. a Coriolis flow meter, in particular
10 an system that prevents false or erroneous measurement and is reliable for use with bunkering operations of larger ocean going vessels.

BACKGROUND OF THE INVENTION

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Large ocean going cargo ships are almost exclusively powered by large multi-cylinder internal combustion engines running on heavy fuel oil. Due to its relatively low cost, most cargo vessels are operated by bunker fuel
20 also known as heavy fuel oil. Bunker fuel comprises a relatively heavy petroleum derivative. There are multiple grades of fuel that may comprise a bunker fuel. Bunker fuel is generally heavier and more viscous than marine diesel.

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Marine fuel costs represent a major portion of a ship's operating costs. With increasing oil prices and increasing conservation efforts, careful fuel management has become vital for environmental and financial reasons.
30 Accurately and reliably measuring of the precise amount of bunker fuel oil that has been transferred on board during a bunkering operation is therefore very important.

Bunkering refers to the practice of storing and transferring marine fuel oils, which have come to be known as bunker fuels. For ship fueling, large amounts of fuel may be temporarily stored in a barge or other
5 container or tank for the purpose of transferring fuel from shore or from the barge to a large ship. Bunker fuel may be located in tanks on a dock or other port facility, or may be carried by a barge or other refueling vehicle.

10 Traditionally, measuring of the amount of heavy fuel that has been delivered is performed by sounding, both in the tanks on the delivery side and in the tanks on the receiving side and the results are then compared. However, using soundings is an inherently inaccurate
15 method since account should be taken for temperature variations, entrapped gas in the bunker fuel, trim, heeling and uncertainty on the received density, which is in practice not feasible and therefore traditional soundings based measurements are not ideal.

20 Therefore, it has been proposed to use flowmeters, such as vibrating flowmeters for providing a more accurate measurement of the amount of heavy fuel and marine gasoil that has been delivered. Vibrating meters, such as for
25 example, vibrating densitometers and Coriolis flow meters are generally known and are used to measure mass flow and other information for materials within a conduit. Known flow meters have one or more conduits of straight or curved configuration. Each conduit configuration in a
30 Coriolis mass flow meter has a set of natural vibration modes, which may be of simple bending, torsional, or coupled type. Each conduit can be driven to oscillate at a preferred mode. Material that flows into the flow meter sensor assembly from a connected pipeline on the inlet

side of the sensor, is directed through the conduit, and exits the sensor through the outlet side of the sensor. The natural vibration modes of the vibrating material filled system are defined in part by the combined mass of the conduits and the material flowing within the conduits. When there is no flow through the sensor assembly, a driving force applied to the conduit causes all points along the conduit to oscillate with identical phase or small "zero offset," which is a time delay measured at zero flow. As material begins to flow through the sensor assembly, Coriolis forces cause each point along the conduit to have a different phase. For example, the phase at the inlet end of the sensor lags the phase at the centralized driver position, while the phase at the outlet leads the phase at the centralized driver position. Pick-off sensors on the conduit produce sinusoidal signals representative of the motion of the conduit. Signals output from the pick-off sensors are processed to determine the phase difference between the pick-off sensors. The phase difference between the two or more pick-off sensors is proportional to the mass flow rate of material flowing through the conduit. The mass flow rate of the material can be determined by multiplying the phase difference by a Flow Calibration Factor (FCF). Prior to installation of the sensor assembly of the flow meter into a pipeline, the FCF is determined by a calibration process. In the calibration process, a fluid is passed through the flow tube at a known flow rate and the relationship between the phase difference and the flow rate is calculated. The sensor assembly of the flow meter subsequently determines a flow rate by multiplying the FCF by the phase difference of the pick-off sensors. In addition, other calibration factors can be taken into account in determining the flow

rate. Improvements in Coriolis flow meters have made it possible to obtain more reliable readings even in the event of entrained air. The readings with known technology are typically at 0.5% accuracy, but often fail
5 due to too much air.

However, the reliability (i.e. whether you get a reading, or whether your reading "fails", i.e. not able to give you a quantity) of vibrating flow meters can be negatively
10 affected if gas or air is present in the flow meter or in the pipe leading to the flow meter. At the beginning and the end of the bunkering operation, the flow meter and the pipe leading thereto may be partially filled with bunker fuel rather than completely empty or completely
15 full. During bunkering, the fuel measurement usually comprises an empty-full-empty batching process, thereby allowing air to be trapped in the system. Bunker fuel is generally heavier and more viscous than e.g. gasoline or diesel and thus a significant amount of air can be
20 trapped in the heavy fuel oil and can be relatively difficult to remove therefrom. A problem can exist especially, whenever flow is stopped, for example at the beginning or at the end of the bunkering process when the valves and pumps delivering the fuel are closed. Air or
25 gas in the system often results in measuring errors and in unreliable results for the measurement of the amount of bunker fuel transferred.

Prior art methods using Coriolis flow meters, such as
30 disclosed in W02102/161922 focus on using fluid switches to detect the presence of bunker fuel at a position just upstream and just downstream of the Coriolis flow meter, and this prior art method is able to delay or stop

measuring (totalizing) when the Coriolis flow meter is not filled completely with bunker fuel. However, this prior art method does provide any measures to effectively avoid having air or gas in the flow meter. Consequently, with this known method the process is often interrupted due to the presence of air or gas and with the interruptions the overall result is not a reliable procedure and measurement.

Consequently, the know approach is inadequate in most situations. Therefore, there is a need in the art to provide an increased reliability for measuring the amount of bunker fuel transferred with a flow meter. There is a need in the art to improve the removal of air or gas from system in which the flowmeter is used. These and other problems are solved and an advance in the art is achieved.

The embodiments described below provide a system and method that substantially improve reliability of measuring the amount of bunker fuel transfer during a bunker fuel operation with a system including vibrating flowmeter.

DISCLOSURE OF THE INVENTION

On the above background it is an object to overcome or at least reduce the problems indicated above.

This object is achieved according to a first aspect by providing a system for measuring the amount of bunker fuel, such as for example heavy fuel oil, transferred during a bunkering activity, the system comprises a pipe extending from an inlet to an outlet, the pipe being

configured to transport bunker fuel from the inlet to the outlet, an air and/or gas separator connected to the pipe at a first position, the air and/or gas separator having a gas and/or air outlet for discharging air and/or gas removed from the pipe, a Coriolis flow meter including a sensor assembly in the pipe and meter electronics, the Coriolis flow meter being configured to measure a flowrate of the bunker fuel as it flows through the Coriolis flow meter, the pipe comprising a downwardly extending portion arranged downstream of the first position and upstream of the Coriolis flow meter, an electronically controlled backpressure valve in the pipe at a position downstream of the Coriolis flow meter, the backpressure valve having an adjustable restriction or throttling effect on any fluid flowing through the backpressure valve, a pressure sensor configured for sensing the pressure in the pipe at a second position downstream of the first position and of upstream of the backpressure valve, and an electronic control unit in electrical communication with the Coriolis flow meter, with the pressure sensor and with the electronically controlled backpressure valve, the electronic control unit being configured to adjust the restriction effect of the backpressure valve using the signal from the pressure sensor in order to maintain the pressure sensed by the pressure sensor close to a predetermined pressure value.

By providing downstream of the Coriolis flow meter an electronically controlled back pressure valve that is connected to an electronic control unit that is in receipt of a signal representing the pressure upstream of the back pressure valve and downstream- and lower than an air and gas separator at first point, and configuring the electronic control unit to maintain a certain pressure

level sensed by the pressure sensor it becomes possible to ensure that the back pressure valve throttles the flow if there is air or gas upstream of the Coriolis flow meter. The restriction or throttling effect of the back pressure valve ensures that any air or gas upstream will take the way of the least resistance through the air or gas separator, thus avoiding air or gas to be included in the bunker fuel flowing through the Coriolis flow meter. The result is that more than 90% of bunkering gives usable readings, the reason being that the air in the system can be handled with the present invention.

According to an implementation of the first aspect the predetermined pressure value substantially corresponds to the static pressure created by a column of bunker fuel with a height that substantially corresponds to the height covered by the downwardly extending portion of the pipe or corresponds to the height difference between the first position and the second position. By keeping the pressure substantially equal to the pressure created by a column of bunker fuel with a height corresponding to the height covered by the downwardly extending portion it becomes possible to keep the target pressure close to the pressure that will exist automatically when the pipe is filled with bunker fuel. If pressure becomes too high the air and gas separator will close avoiding that bunker fuel will be forced out through the air and gas separator and it is also ordered that the pressure becomes too low so that there is a risk of air or gas to be included in the bunker fuel that is passing through the Coriolis flow meter.

According to another implementation of the first aspect the electronic control unit is configured to adjust the

position and thereby increase the restriction or throttling effect of the backpressure valve when the pressure detected by the pressure sensor is below a first threshold, and to adjust the position and thereby
5 decrease the restriction or throttling effect of the backpressure valve when the pressure detected by the pressure sensor is above a second threshold that is higher than the first threshold.

10 According to another implementation of the first aspect of the first threshold is slightly below the static pressure created by a column of bunker fuel with a height that substantially corresponds to the height covered by the downwardly extending portion of the pipe, and the
15 second threshold is slightly above the static pressure created by a column of bunker fuel with a height that substantially corresponds to the height covered by the downwardly extending portion of the pipe.

20 According to yet to another implementation of the first aspect the gas and/or air outlet of the air separator is connected to the atmosphere via conduit to an overflow tank, the conduit including detection means such as a sight glass for verifying that no bunker fuel is flowing
25 to the overflow tank.

According to another implementation of the first aspect the inlet comprises a bunkering manifold, preferably the inlet comprising two bunkering manifolds, one bunkering
30 manifold being suitable to form a port bunkering manifold of a ship and the other bunkering manifold being suitable for forming the starboard bunkering manifold of a ship.

According to another implementation of the first aspect the outlet is connected to a bunker fuel tank.

5 According to another implementation of the first aspect the downwardly extending portion includes a substantially vertically extending drop pipe section.

10 According to another implementation of the first aspect the first position where the air separator connects to the pipe is close to or at the upper end of the drop pipe section.

15 According to another implementation of the first aspect the second position where the pressure sensor connects to the pipe is close to or at the lower end of the drop pipe section.

20 According to another implementation of the first aspect the system further comprises a first fluid switch located just upstream of the Coriolis sensor to determine if the pipe just upstream of the Coriolis sensor is filled with bunker fuel and a second fluid switch located just downstream of the Coriolis sensor to determine if the pipe just downstream of the Coriolis sensor is filled
25 with bunker fuel, the electronic control unit being in electrical communication with the first fluid switch and with second fluid switch, and the electronic control unit being configured to start measuring the a flowrate of the bunker fuel only when both the first fluid switch and the
30 second fluid switch indicate the presence of bunker fuel in the pipe.

According to another implementation of the first aspect the electronic control unit is configured to stop

measuring a flowrate of the bunker fuel when one of the fluid switches indicates that the pipe at the position of the fluid switch concerned is not filled with bunker fuel.

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The object above is also achieved in accordance with a second aspect by providing large ocean going ship with a system as defined above, wherein the inlet of the pipe is connected to a port bunker manifold of the ship and to a starboard bunker manifold of the ship and the outlet of the pipe is connected to a bunker oil fuel tank of the ship.

The object above is also achieved in accordance with a third aspect by providing a method for transferring bunker fuel from a barge or other container to a bunker fuel tank in a ship, using a pipe, the pipe including a Coriolis flow meter configured for measuring a flow of bunker fuel through the pipe and a restriction or throttling valve downstream of the Coriolis flow meter, an air or gas vent being connected to the pipe at a first position where the pipe is higher than- and upstream of the Coriolis flow meter, the method comprising measuring a pressure in the pipe at a second position between the air or gas vent and the Coriolis flow meter, the second position being lower than the first position, gradually increasing a pumping rate of bunker fuel into the pipe to a nominal pumping rate, and applying a high restriction or throttling effect with the restriction or throttling valve until the measure pressure exceeds a first threshold.

According to another implementation of the third aspect the method further includes after the measured pressure

has exceeded the first threshold: adjusting the restriction or throttling effect of the restriction or throttling valve with the aim to keep the measured pressure above the first threshold by increasing the
5 restriction or throttling effect and below a second threshold that is slightly higher than the first threshold be reducing the restriction or throttling effect.

10 According to another implementation of the third aspect the first threshold substantially corresponds to the static pressure created by a column of bunker fuel with a height that substantially corresponds to the height difference between the first position and the second
15 position.

According to another implementation of the third aspect the a vent line is connected to the venting position, the method further comprising periodically checking for
20 bunker fuel in the vent line.

Further objects, features, advantages and properties of the system, ship and method disclosed herein will become apparent from the detailed description.

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BRIEF DESCRIPTION OF THE DRAWINGS

In the following detailed portion of the present description, the aspects and implementations will be
30 explained in more detail with reference to the exemplary embodiments shown in the drawings, in which:

Fig. 1 is a side view of a cargo ship according to an example embodiment,

Fig. 2 is a rear view of the cargo ship of Fig. 1 and of a bunkering barge during a bunkering operation,

Fig. 3 is a diagrammatic representation of a bunker fuel transfer and measuring system,

5 Fig. 4 is a sectional view at an air/gas separation point in Fig. 3 and

Fig. 5 is a diagram of a method of transferring bunker fuel and measuring the transferred bunker fuel.

10 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 shows a large ocean going cargo ship 1 according to an exemplary embodiment in side view. In this embodiment the large ocean going cargo ship 1 is a
15 container ship. However, the ship or freighter 1 could just as well be a general cargo vessel, a tanker, a dry-bulk carrier, a multipurpose vessel, a reefer ship, a passenger ship or any other large ocean going type of cargo ship that uses liquid fuel, such as e.g. fuel oil
20 or heavy fuel oil.

The large ocean going cargo ship 1 has a hull 2 and one or more engine rooms 3 provided inside the hull 2. The large ocean going cargo ship 1 is powered by one or more
25 large self-igniting internal combustion engines 4, i.e. four-stroke or two-stroke self-igniting combustion engines 4 located in an engine room 3. The large self-igniting internal combustion engine(s) 4 drive(s) the propellers(s) and there may be one or more auxiliary
30 engines (generator sets) that provide electrical power and heat for various consumers of electrical power aboard the large ocean ship 1.

At least one fuel tank 8 is provided in the hull 2 in a suitable location. Typically, there will be several interconnected bunker fuel tanks 8. If the vessel is operated with heavy fuel oil the tank or tanks 8 for heavy fuel oil will be heated at all times to ensure that the heavy fuel oil remains flowable. Separate tanks for fuel oil will also be provided so that the engine 4 can be operated with fuel oil if needed.

10 The large ocean going cargo ship 1 also has one or more funnels 6 and a bridge 7. Containers are shown on the deck in container bays filled with rows of containers in a plurality of tiers. Containers can also be stowed inside cargo space in the hull 2.

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Fig. 2 is a diagrammatic rear view of the ocean going ship 1 when it is moored and a bunkering barge 5 alongside and with the starboard bunkering manifold 9 connected to the bunkering barge via a hose 12 that is supported by a crane of the bunkering barge 5. The ocean going ship 1 could also receive bunker fuel from tanks or other storage facilities on shore using the port bunkering manifold 9. At the start of a bunkering operation the bunkering barge 5 is moored and alongside the ocean going ship 1 and the free end of hose 12 is connected to one of the two bunkering manifolds 9. During the bunker fuel transfer bunker fuel is pumped from a bunker fuel tank 40 in the bunkering barge 5 via the pipe or hose 12 to one of the bunker manifolds 9 and from there is flows into the bunker fuel tank 8 in the oceangoing ship 1. The transfer procedure of the bunker fuel from the barge 5 to the ocean going ship 1 through the hose 12 will be described in greater detail further below.

Fig. 3 shows diagrammatically a system 10 for transferring bunker fuel from a storage facility, such as a bunkering barge 5 to a recipient, such as e.g. a bunker fuel tank 8, i.e. a custody transfer. As can be appreciated, in such a situation, it is desirable to determine the precise amount of fuel that is transferred as well as possibly the quality, grade, purity, etc. It is also desirable that the measurement is automated and free from human intervention. Therefore, the system 10 is configured for measuring the amount of bunker fuel that is transferred during a bunkering operation. The bunker fuel can be fuel oil or heavy fuel oil, the system being particularly useful for heavy fuel oil. but is just as suitable for marine gasoil.

The system 10 includes a pipe 11 that extends from an inlet of the pipe 11 to an outlet of the pipe. The pipe 11 may comprise a preexisting pipe that is part of a larger system. In this embodiment the inlet of the pipe 11 is formed by a bunkering manifold 9 and the outlet of the pipe 11 is connected to the bunker fuel tank 8. Aboard a large ocean going ship 1 there will be a port bunkering manifold 9 and also a starboard bunkering manifold 9, the pipe 11 being connected to both bunkering manifolds 9, i.e. the pipe 11 has two inlets. The bunkering manifolds 9 are typically arranged at deck level whilst the bunker fuel tank 8 is arranged in the ship 1 at a level below deck level.

The port bunkering manifold 9 and the starboard bunkering manifold 9 are each provided with a flange that is configured for connection to a hose 12 that extends from a source of bunker fuel, such as the bunkering barge 12.

In some case the hose 12 is suspended from a crane on the bunkering barge 5 (the crane can also be on shore). The bunkering barge 5 is provided with a bunker fuel tank 40 that contains an amount of bunkering fuel to be transferred to the bunker fuel tank 8 aboard the ship 1. A pipe or other suitable conduit connects the bunker fuel tank 40 with the hose 12. The bunkering barge 5 is provided with a bunker fuel pump 41 that is configured to pump the bunker fuel from the bunker fuel tank 40 to the hose 12.

The hose 12 is connected to the inlet of a pipe 11 at the bunker manifold 9. If the fuel is heavy fuel oil the tank 40 will be heated so that the heavy fuel oil remains flowable and the bunkering fuel tank 8 aboard the ocean going ship 1 will also be heated at all times to keep the heavy fuel flowable.

The pipe 11 extends from its inlets at the bunkering manifolds 9 to an outlet that is in this embodiment connected to the bunker fuel tank 8. The bunker fuel that is to be transported into the bunker fuel tank 8 enters at one of the bunkering manifolds 9 and flows through the pipe 11 to the bunker fuel tank 8. Thus, the flow direction of the fuel through the pipe 11 is under normal circumstances always from the inlet at the bunkering manifold 9 to the outlet at the bunker fuel tank 8.

The bunkering manifold 9 is typically arranged at deck level. A manifold valve 13 is arranged in the pipe 11 just downstream, i.e. close to, each of the bunkering manifolds 9. The manifold valve 13 is a valve that can open and close manually by an operator.

Downstream of the manifold valve 13 the pipe 11 extends downwards in order to cover a height difference "h". The height difference can as shown be covered by a substantially vertically extending drop pipe 15, but it is understood that the height difference "h" could also be covered by a sloping section of the pipe 11. Thus, in the present embodiment the pipe 11 comprises a substantially vertically extending drop pipe 15.

10 An air and gas separation point 27 is provided at a first position in the pipe 11 downstream of the manifold valve 13, preferably close or at to the position where the pipe 11 starts to extend in a downward direction. Thus, the air separation point 27 is arranged at a first position
15 where the pipe 11 is at its highest, or at least close to a position where the pipe 11 is at its highest. An air/gas separator 14 is connected to the pipe 11 at the air/gas separation point 27. The air/gas separator 14 can also be provided in the pipe 11, at or near the highest
20 position of the pipe 11 and before the pipe 11 starts to extend downwards. Fig. 4 shows the air/gas separator 14 at a slightly larger scale than Fig.3, with the pipe 11 shown in cross-sectional view. The air separator is in an embodiment connected at the air separation point 27 to
25 the top of the pipe 11 (as shown in Fig. 4) by a feed conduit 28. Thus, the air separation point 27 is located at the highest point of the pipe 11 for facilitation of collection and removal of air or gas from pipe 11. The air/gas separator 14 is provided with a housing with a
30 chamber connected to an inlet at its lower end and with an outlet at a higher position, The chamber contains a floating device (e.g. a cylinder or ball - represented in

Fig. 4 by a ball) that when lifted closes off the outlet port. Thus when liquid (bunker fuel) enters the chamber the floating device is lifted and blocks the outlet port, thus no bunker fuel can escape. If bunker fuel level
5 drops the outlet port is opened and any air/gas that is present can escape again.

A gas/air evacuation pipe 26 connects the outlet of the air/gas separator 14 to an overflow tank 32. A sight
10 glass spinner 30 is arranged in the air/gas evacuation pipe 26 to detect the presence of bunker fuel in the air/gas evacuation pipe. The presence of bunker fuel in the air/gas evacuation pipe 26 is undesirable, but in case any bunker fuel should inadvertently enter the
15 air/gas evacuation pipe 26 this fuel bunker fuel is collected in the overflow tanks 32. The overflow tank 32 is provided with a vent pipe 34 that allows any excess air/gas to be vented to the atmosphere.

20 A first pressure sensor 16 is connected to the pipe 11 at a second position where the pipe has extended downwards over a distance that corresponds to the height "h". Thus, the height difference between the first position of the air/ separation point 27 and the second position of the
25 first pressure sensor 16 is equal to the height indicated by the letter "h" in Fig. 3. The first pressure sensor 16 detects the pressure in the pipe 11 at the second position and the first pressure sensor 16 is connected via a signal cable (lead) to an electronic control unit
30 50. Thus, the electronic control unit 50 is in receipt of a signal corresponding to the pressure in the pipe 11 at the location where the first pressure sensor 16 is connected to the pipe 11.

When the pipe 11 upstream of the second position is filled with bunker fuel, and no further pressure is applied to the incoming bunker fuel, the static pressure at the first pressure sensor 16 will approximately be equal to the pressure at the bottom of a column of bunker fuel with a height h , i.e. $P = \rho * g * h$, with P being the pressure, ρ being the volumetric mass density of the bunker fuel, g representing the Earth's standard acceleration due to gravity, and h being the height difference between the first position in the second position. This static pressure will hereafter be referred to as the target pressure.

Downstream of the downwardly extending portion of the pipe 11 a vibrating flow meter 20 is provided. In the present embodiment the vibrating flow meter 20 is a Coriolis flow meter 20 that includes a preferably U-shaped pipe section, preferably a double U-shaped pipe section. The Coriolis flow meter 20 includes a sensor assembly and is connected via leads to meter electronics 34. The meter electronics 34 are configured to create a signal representing the flow rate of bunker fuel flowing through the Coriolis flow meter 20. The meter electronics, connected to the sensor assembly can be configured to measure one or more characteristics of bunker fuel flowing through the Coriolis flow meter 20, such as, for example, density, mass flow rate, volume flow rate, totalized mass flow, and other information. Further, it should be appreciated that while the vibrating meter 20 is described as comprising a Coriolis flow meter, the vibrating meter 20 could just as easily comprise another type of vibrating meter, such as a vibrating densitometer, a vibrating volumetric flow

meter, or some other vibrating meter that lacks all of the measurement capabilities of Coriolis flow meters. Therefore, the present embodiment should not be limited to Coriolis flow meters. Rather, the meter electronics 34
5 may be in communication with other types of sensor assemblies, with a flowing fluid or a stationary fluid.

The meter electronics 34 can process the sensor signals in order to obtain one or more flow characteristics of
10 the material flowing through the Coriolis flow meter 20. It should be understood that the meter electronics 20 may include various other components and functions that are generally known in the art. These additional features are omitted from the description and figures for the purpose
15 of brevity. Therefore, the present embodiment should not be limited to the specific embodiments shown and discussed.

The meter electronics 34 is connected to the electronic
20 control unit 50 via a communication cable. Thus, the electronic control unit 50 is in response of a signal from the Coriolis flow meter 20 that represents the flow rate of bunker fuel through the Coriolis flow meter 20.

25 A first fluid switch 17 is connected to the pipe 11 just upstream of the Coriolis flow meter 20. The first fluid switch 17 is in an embodiment configured to detect the presence of liquid in the pipe 11, i.e. it forms a liquid detector. The first fluid switch signal can comprise a
30 signal indicating one or more flow conditions, such as a liquid level, upstream of the flowmeter 20. The first fluid switch 17 is connected to the electronic control unit 50 via a signal cable. Thus, the electronic control unit 50 is in receipt of a signal indicating the presence

liquid in the pipe 11 at the position of the first fluid switch 17. A second fluid switch 19 that is otherwise identical to the first fluid switch 17, is arranged just downstream of the Coriolis flow meter 20. The second
5 fluid switch 19 is also connected to the electronic control unit 50 by a signal cable. Thus, the electronic control unit 50 is in receipt of a signal indicating the presence of liquid in the pipe 11 at the position of the second fluid switch 19.

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A second pressure sensor 18 is connected to the pipe 11 downstream of the Coriolis flow meter 20. A signal cable connects the second pressure sensor 18 to the electronic control unit 50.

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A temperature sensor 21 is connected to the pipe 11 at a position downstream of the Coriolis flow meter 20. The temperature sensor 21 is connected to the electronic control unit 50 by a signal cable, and thus the
20 electronic control unit 50 is in receipt of a signal indicating the temperature of any liquid in the pipe at the position of the temperature sensor 21.

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A back pressure valve 22 is arranged in the pipe 11 at a position downstream of the Coriolis flow sensor 20 and downstream of the second pressure sensor 18. The fluid switch 19 must be arranged between the Coriolis flow sensor 20 and the back pressure valve 22.

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The back pressure valve 22 has a range of positions and is capable of applying an adjustable degree of restriction or throttling to the fluid flowing through the back pressure valve 22, the degree of restriction or throttling depending on the position of the back pressure

valve 22. Hereto, the back pressure valve 22 includes a restricting element, such as a variable size orifice or other suitable means to apply a variable restriction to the fluid flowing through the back pressure valve 22, which is in an embodiment a butterfly valve. The backpressure valve 22 can be of any suitable type e.g. butterfly valve or a ball valve, preferably a valve where there is no risk that a pressure drop will occur after the backpressure valve 22. This is required since the bunker fuel tanks 8 are filled from the bottom. If a backpressure valve 22 is used where a pressure drop can occur then the back pressure valve needs to be specially designed in order to avoid cavitation of the backpressure valve.

The position of the restricting element is electronically adjusted. The back pressure valve 22 is an electronically controlled valve, so that an electric signal can be used to adjust the opening or the degree of restriction or throttling that is applied.

The back pressure valve 22 is connected to the electronic control unit 50 via a signal cable. Thus, the electronic control unit 50 can communicate a control signal to the back pressure valve 22 in order to arrange that the back pressure valve 22 has the correct position, i.e. applies the correct amount of restriction throttling to the fluid flowing there through. In an embodiment, the back pressure valve 22 communicates a signal representing the position of the restriction or throttling element to the electronic control unit 50.

The electronic control unit 50 is connected to a general-purpose computer, a micro processing system, a logic

circuit, or some other general purpose or customized processing device. The general purpose computer 55 is provided with a user interface. The computer 55 is connected to the electronic control unit via a signal cable or via a wireless connection and the computer can be 55 can be located near the electronic control unit, or be at a remote location. The remote location can be on the oceangoing ship 1 can be at another location, such as for example in the headquarters of a shipping company that operates the oceangoing ship 1.

As shown in Fig. 3, the various sensors, meter electronics, and backpressure valve are in electrical communication with the electronic control unit 50 via leads. It should be appreciated however, that in other embodiments, the various sensors, switches, valves and electronics a may be in communication via a wireless interface.

The electronic control unit 50 is configured to attempt to maintain a predetermined pressure such as the above-mentioned target pressure, in the drop pipe 15 at the second position as measured by the first pressure sensor 16. Hereto, the electronic control unit 50 is configured to adjust and control the position of the back pressure valve 22 in there with the restriction effect of the back pressure valve 22 accordingly.

Specifically, the electronic control unit 50 is configured to respond by adjusting the back pressure valve 22 to increase the throttling effect thereof when the pressure that is detected by the first pressure sensor 16 falls below a first threshold and the electronic control unit 50 is configured to respond by

adjusting the back pressure valve 22 to decrease the throttling effect thereof when the pressure that is detected by the first pressure sensor 16 exceeds a second threshold. The first threshold being slightly lower than
5 the above-mentioned predetermined pressure and the second threshold being slightly higher than the above-mentioned predetermined pressure. In an embodiment the predetermined pressure is the above-mentioned target pressure that corresponds to the pressure at the bottom
10 of a column of bunker fuel with a height h .

When air or gas is present in the downwardly extending portion of the pipe 11, specifically in the drop pipe 15, the pressure measured at the second position will be
15 lower than the target pressure. In practice it has been shown that the dynamic pressure effects of the bunker fuel being pumped through the pipe 11 to not play a significant role. Thus, when the pressure measured by the first pressure sensor 16 falls below the target pressure,
20 it can be assumed that there is air or gas in the pipe 11 upstream of the second position. Thus, when the first pressure sensor 16 measures a pressure below the target pressure the electronic control unit 50 will instruct the back pressure valve 22 to increase its restriction or
25 throttling effect. This increased restriction will cause the pressure in the pipe 11 upstream of the back pressure valve to increase and the increased pressure will facilitate the removal of any gas or air in the pipe 11 upstream of the back pressure valve through the air/gas
30 separator 14. As soon as the undesirable gas/air has been removed the pressure measured by the first pressure sensor 16 will increase and when the pressure rises to a given extent above the target pressure the electronic control unit 50 will instruct the back pressure valve 22

to reduce its restriction effect. A too high pressure in the pipe 11 at the second position is undesirable because this will create a too high back pressure for the pump 41 and risk for the hose 12 to bust.

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Thus, the system 10 is configured with a closed loop feedback control system that controls the pressure in the pipe at 11 at the second position with the aim to keep this pressure close to the target pressure. By keeping
10 the pressure at the second position close to the target pressure the evacuation or removal of air and gas from the pipe 11 through the air separator 14 is facilitated.

Fig. 5 illustrates a method of transferring bunker fuel
15 and measuring the amount transferred. As mentioned above, after the bunkering manifold 9 is connected to a source of bunker fuel, such as a barge 5, a pump associated with the source of bunker fuel will be used to pump bunker fuel into the pipe 11. After connection of a hose 12 or
20 the like to the bunkering manifold, the packing phase is started and the electronic control unit 50 instructs in step 101 the back pressure valve 22 to be closed or almost closed so that it will apply a high restriction effect at the start of the bunker fuel transfer
25 procedure, i.e. the packing phase. The operator opens the manifold valve 13 in step 102.

Thereafter, pumping bunker fuel from the source of bunker fuel into the pipe 11 is slowly started in step 103. Via
30 the first and second liquids switches 17,19 the electronic control unit 50 monitors whether bunker fuel is present both just upstream and just downstream of the Coriolis flow meter 20. The electronic control unit 50 will monitor the presence of bunker fuel with the liquid

sensors 17,19 throughout the bunker fuel transfer procedure, and the electronic control unit is configured, step 105, to start measuring the amount of bunker fuel transferred (i.e. start totalizing the flow rate) soon as
5 both liquid switches 17, 19 have a positive signal.

The pressure at the low-end of the drop pipe 15 is measured with the first pressure sensor 16, step 105. If the measured pressure is below a first threshold, which
10 is typically a pressure slightly below the above-mentioned target pressure, the electronic control unit 50 gradually closes the back pressure valve 22 to increase its restricting effect, step 106 and 111.

15 Keeping the back pressure valve 22 closed or nearly closed, i.e. applying a high restriction effect, during the packing phase ensures that any air or gas that is present in the system (coming from hose 12 or being present in pipe 11 before pumping started) will be
20 evacuated effectively via the air/gas separator 14 because the flow path through the back pressure valve 22 has a high resistance thereby causing the air/gas to take out the way of the least resistance through the air/gas separator 14.

25

When the electronic control unit 50 determines that pressure sensor 16 gives a signal that the measured pressure is over the first threshold, step 106, the pipe 11 is fully packed with bunker fuel and any air or gas
30 that was trapped at the start of the bunkering procedure has now been evacuated, thus, ending the packing phase and starting the transfer phase.

Upon entering the transfer phase the pumping rate is gradually increased towards the normal pumping rate, step 111. During the transfer of bunker fuel at a preferably normal pumping rate the pressure at the low-end of the droppipe 15 is continuously or regularly monitored by the electronic control unit 50 on the basis of the signal from the first pressure sensor 16, step 112. If the measured pressure is below the first threshold, step 113, the electronic control unit 50 sends a signal to the electronically controlled back pressure valve 22, step 114, to increase the restriction effect of the back pressure valve 22 to thereby cause an increase in the pressure upstream of the back pressure valve 22. Thereafter, the process moves to step 117 which will be described in detail further below.

If the measured pressure at the second position is not below the first threshold the process moves to step 115, where the electronic control unit 50 determines if the measured pressure is above a second threshold, which is in an embodiment a pressure slightly above the above-mentioned target pressure. If the measured pressure is above the second threshold the process moves to step 116, where the electronic control unit 50 instructs the electronically controlled back pressure valve 22 to adjust its position to decrease its restriction effect to thereby decrease the pressure in the pipe 11 upstream of the back pressure valve 22.

Thus, if during the transfer phase any air or gas is present in the drop pipe, for example because large amount of air were bumped into the pipe 11 from the hose 12, the pressure measured and the second position with the first pressure sensor 16 will drop and the electronic

control unit will respond by increasing the restriction effect of the back pressure valve 22. The resulting pressure increase upstream of the back pressure valve will facilitate removing the air in the droppipe 15 via the air/gas separator 14.

If the measured pressure is between the first and second threshold (i.e. the pressure is in the desired range), or after any adjustment of the back pressure valve 22 in step 114 or step 116, the process moves to step 117 where the electronic control unit 50 checks if an end of bunkering signal is received (e.g. from an operator via the computer 55) or if one of the liquid sensors 17, 19 gives a negative signal indicating that the pipe 11 at the liquid sensor concerned is not filled with bunkering fuel. If no end of bunkering signal is received and both liquid sensors 17,19 are positive, the process moves again to step 112 and the above part of the process is repeated until the end of bunkering signal is received or until both the liquid sensors 17,19 is negative.

When the end of bunkering signal is received or when both of the liquid sensors 17,19 is negative the process moves to step 121 and enters the end phase of the bunker fuel transfer and measuring process. From the moment that both of the liquid sensors 17,19 is negative the electronic control unit stops measuring the transfer of bunker fuel, i.e. stops totalizing the flow rate. When the process moves to the end phase, the pumping rate is gradually decreased to stop. When pumping has stopped, the electronic control unit 50 instructs the back pressure valve 22 to move to its most closed position with the largest restriction effect e.g. 10% open so that gravity can pull any remaining bunker fuel in pipe 11 to the

bunker fuel tank 8, step 122. When all bunker fuel has been evacuated from the pipe 11, the liquid sensors 17,19 will send the end signal to the electronic control unit 50, the manifold valve 13 can be closed air can be drawn in by air/gas separator 14, step 123 and the bunker fuel transfer and measuring process ends.

Although the aspects and implementations of the present disclosure have been described in detail for purpose of illustration, it is understood that such detail is solely for that purpose, and variations can be made therein by those skilled in the art without departing from the scope of the claims.

The term "comprising" as used in the claims does not exclude other elements. The term "a" or "an" as used in the claims does not exclude a plurality.

CLAIMS:

1. A system (10) for measuring the amount of bunker fuel,
such as for example heavy fuel oil, transferred during a
5 bunkering activity, said system (10) comprises:

a pipe (11) extending from an inlet (9) to an outlet,
said pipe (11) being configured to transport bunker fuel
from said inlet (9) to said outlet,

10

an air and/or gas separator (14) connected to said pipe
(11) at a first position, said air and/or gas separator
(14) having a gas and/or air outlet for discharging air
and/or gas removed from said pipe (11),

15

a Coriolis flow meter (20) including a sensor assembly in
said pipe (11) and meter electronics (34), said Coriolis
flow meter (20) being configured to measure a flowrate of
the bunker fuel as it flows through said Coriolis flow
20 meter (20),

said pipe (11) comprising a downwardly extending portion
(15) arranged downstream of said first position and
upstream of said Coriolis flow meter (20),

25

an electronically controlled backpressure valve (22) in
said pipe (11) at a position downstream of said Coriolis
flow meter (20), said backpressure valve (22) having an
adjustable restriction effect on any fluid flowing
30 through said backpressure valve (22),

a pressure sensor (16) configured for sensing the
pressure in said pipe (11) at a second position

downstream of said first position and of upstream of said backpressure valve (22), and

an electronic control unit (50) in electrical
5 communication with said Coriolis flow meter (20), with said pressure sensor (16) and with said electronically controlled backpressure valve (22),

10 said electronic control unit (50) being configured to adjust the restriction effect of said backpressure valve (22) using the signal from said pressure sensor (16) in order to maintain the pressure sensed by said pressure sensor (16) close to a predetermined pressure value.

15 2. A system (10) according to claim 1, wherein said predetermined pressure value substantially corresponds to the static pressure created by a column of bunker fuel with a height that substantially corresponds to the height (h) covered by said downwardly extending portion
20 (15) of said pipe (11) or corresponds to the height difference between said first position and said second position.

25 3. A system (10) according to claim 1 or 2, wherein said electronic control unit (50) is configured:

to adjust the position and thereby increase the restriction effect of said backpressure valve (22) when the pressure detected by said pressure sensor
30 (16) is below a first threshold, and

to adjust the position and thereby decrease the restriction effect of said backpressure valve (22) when the pressure detected by said pressure sensor

(16) is above a second threshold that is higher than said first threshold.

4. A system (10) according to claim 1 or 2, wherein:

5

said first threshold is slightly below the static pressure created by a column of bunker fuel with a height that substantially corresponds to the height (h) covered by said downwardly extending portion (15) of said pipe (11), and

10

said second threshold is slightly above the static pressure created by a column of bunker fuel with a height that substantially corresponds to the height (h) covered by said downwardly extending portion (15) of said pipe (11).

15

5. A system (10) according to any one of claims 1 to 4, wherein said gas and/or air outlet of said air separator (14) is connected to the atmosphere via conduit (26) to an overflow tank (32), said conduit (26) including detection means such as a sight glass (30) for verifying that no bunker fuel is flowing to said overflow tank (32).

25

6. A system (10) according to any one of claims 1 to 5, wherein said inlet comprises an bunkering manifold (9), preferably said inlet comprising two bunkering manifolds (9), one bunkering manifold being suitable to form a port bunkering manifold of a ship (1) and the other bunkering manifold being suitable for forming the starboard bunkering manifold (9) of a ship (1).

30

7. A system (10) according to any one of claims 1 to 6, wherein said outlet is connected to a bunker fuel tank (8).

5 8. A system (10) according to any one of claims 1 to 7, wherein said downwardly extending portion includes a substantially vertically extending droppipe section (15).

9. A system (10) according to claim 8, wherein said first
10 position where said air separator (14) connects to said pipe (11) is close to or at the upper end of said droppipe section (15).

10. A system (10) according to claim 8 or 9, wherein said
15 second position where said pressure sensor (16) connects to said pipe (11) is close to or at the lower end of said droppipe section (15).

11. A system (10) according to any one of claims 1 to 7,
20 further comprising a first fluid switch (17) located just upstream of said Coriolis sensor (20) to determine if the pipe (11) just upstream of said Coriolis sensor (20) is filled with bunker fuel and a second fluid switch (19) located just downstream of said Coriolis sensor (20) to
25 determine if the pipe (11) just downstream of said Coriolis sensor (20) is filled with bunker fuel, said electronic control unit (50) being in electrical communication with said first fluid switch (17) and with second fluid switch (17), and said electronic control
30 unit (50) being configured to start measuring the a flowrate of the bunker fuel only when both the first fluid switch (17) and the second fluid switch (19) indicate the presence of bunker fuel in the pipe(11).

12. A system (10) according to claim 11 wherein said electronic control unit (50) being configured to stop measuring the flowrate of the bunker fuel when both of said fluid switches (17,19) indicates that the pipe (11) at the position of the fluid switch concerned is not filled with bunker fuel.

13. A large ocean going ship (1) with a system (10) according to claim any one of claims 1 to 11, wherein the inlet of said pipe (11) is connected to a port bunker manifold (9) of said ship (1) and to a starboard bunker manifold (9) of said ship (1) and the outlet of said pipe (11) is connected to a bunker oil fuel tank (8) of said ship (1).

15

14. A method for transferring bunker fuel from a barge or other container to a bunker fuel tank (8) in a ship (1), using a pipe (11), said pipe (11) including a Coriolis flow meter (20) configured for measuring a flow of bunker fuel through said pipe (11) and a restriction or throttling valve (22) downstream of said Coriolis flow meter (20), an air or gas vent (27) being connected to said pipe (11) at a first position where said pipe (11) is higher than- and upstream of said Coriolis flow meter (20), said method comprising:

25

measuring a pressure in said pipe (11) at a second position between said air or gas vent (27) and said Coriolis flow meter (20), said second position being lower than said first position,

30

increasing a pumping rate of bunker fuel into said pipe (11) to a nominal pumping rate, and

applying a high restriction or throttling effect with said restriction or throttling valve (22) until said measure pressure exceeds a first threshold.

5 15. A method according to claim 14, further including after said measured pressure has exceeded said first threshold: adjusting said restriction or throttling effect of said restriction or throttling valve (22) with the aim to keep said measured pressure above said first
10 threshold by increasing said restriction or throttling effect and below a second threshold that is slightly higher than said first threshold by reducing said restriction or throttling effect.

15 16. A method according to claim 14 or 15, wherein said first threshold substantially corresponds to the static pressure created by a column of bunker fuel with a height that substantially corresponds to the height difference (h) between said first position and said second position.

20 17. A method according to any one of claims 14 to 16, wherein a vent line (26) is connected to said venting position (27), said method further comprising periodically checking for bunker fuel in said vent line
25 (26).