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EXHAUST CAPTURE DEVICES AND METHODS

Abstract

A system of controlling the capture of emissions from an exhaust emitter includes a housing including an inlet, a first outlet, and a second outlet; an adapter configured to attach to the exhaust emitter and the inlet of the housing; an attachment assembly coupled to the exhaust emitter, the attachment assembly including at least one leg pivotably coupled to the adapter; at least one valve coupled to the housing; and a control unit capable of communicating with the at least one valve to control the emission of exhaust through the device.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] The application is a continuation application of U.S. Ser. No. 18/127,433 filed Mar. 28, 2023, which claims the benefit of continuation application U.S. Ser. No. 17/847,983, filed on Jun. 23, 2022, now U.S. Pat. No. 11,635,012 issued on Apr. 25, 2023, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE DISCLOSURE

[0002] The present disclosure generally relates to devices, systems, and methods for automatic hermetic capture of aftertreatment for a variety of exhaust-producing devices, such as diesel engines of ships in harbors, industrial chimneys in cities, and stacks at powerplants. While the preferred embodiment herein describes the capture of exhaust from a ship's exhaust outlet, the devices, systems, and methods described herein can be implemented with any exhaust-producing device to facilitate the automatic capture of aftertreatment. The hermetic aftertreatment capture process allows the exhaust to maintain a constant temperature throughout the post-treatment process via at least one hermetic seal. This seal enables high efficiency of the abatement process and high purity of filtered output. Further, this process provides a conservation of energy for the reutilization of the output for desorbing and for parallel processes like capturing certain gases, such as CO.sub.2.

[0003] When a ship comes to port, it can moor itself under its own engine power. Alternatively, the mooring of a ship can be carried out by a special tow that connects to the ship entering the port and leads the ship to the mooring area. While this mooring takes place, the ship's primary engines may be shut off and auxiliary engines and boilers may be turned on to supply power to the ship while in port. Thus, under either the ship's primary engines or its auxiliary engines, exhaust will flow from the engines out of a stack or funnel into the atmosphere.

[0004] Most modern ships have diesel engines that run on fuels such as HFO (heavy fuel oil), IFO (intermediate fuel oil), LSMGO (low sulfur maritime gas oil), VLSMGO (very low sulfur), and ULSMGO (ultra-low sulfur). Currently, many regulations require ships to switch from HFO or IFO to LSMGO as the ships enter a harbor or port area, and to continue using LSMGO until the ship leaves the harbor. Switching fuels to a lower grade fuel typically results in the ship emitting less sulfur into the atmosphere. Due to the proliferation of cargo shipping in recent years, some harbors remain backlogged and require ships to idle for several days before they can be moored. While switching fuel types limits some of the emissions the ships produce, cities surrounding the harbors are subject to increased pollution from the ships and that increased pollution can directly harm the health and wellness of the cities' residents.

[0005] In addition to sulfur pollution, diesel engines often produce other air pollutants including particulate matter (PM), heavy metals (HM), nitrogen oxides (NO.sub.x), and other volatile organic compounds. Accordingly, a system of safely and efficiently capturing multiple types of harmful emissions from ships while ships idle in and around ports is desired. Such a system is described herein.

BRIEF SUMMARY OF THE INVENTION

[0006] According to one aspect, a system of controlling the capture of emissions from an exhaust emitter comprises a housing including an inlet, a first outlet, and a second outlet; an adapter configured to attach to the exhaust emitter and the inlet of the housing; an attachment assembly coupled to the exhaust emitter, the attachment assembly including at least one leg pivotably coupled to the adapter; at least one valve coupled to the housing; and a control unit capable of communicating with the at least one valve to control the emission of exhaust through the device.

[0007] According to another aspect, the at least one valve includes a first valve located between the housing and the first outlet, and a second valve located between the housing and the second outlet.

[0008] According to a different aspect, the exhaust emitter is at least one of an exhaust-producing funnel of a ship, a smokestack of a power plant, or a chimney of an industrial system.

[0009] According to another aspect, the at least one leg includes six legs positioned radially around a shaft.

[0010] According to yet another aspect, the attachment assembly further comprises a motor and a gear assembly, the gear assembly operably coupling the shaft to the motor.

[0011] According to another aspect, the shaft includes teeth configured to mate with a gear of the gear assembly.

[0012] According to a different aspect, a system for capturing exhaust from a stack comprises a housing including at least one inlet and at least one outlet; an actuator operably coupled to a gear assembly; a shaft within the housing operably coupled to the gear assembly, the shaft attached to at least one leg configured to engage the stack; at least one valve attached to the housing at the least one outlet; and at least one sensor in communication with a control unit, the control unit configured to adjust the at least one valve based on a reading from the at least one sensor.

[0013] According to another aspect, the system further comprises an adaptor configured to couple with and create a hermetic seal with the housing and with the stack.

[0014] According to another aspect, the adaptor is selectable according to the stack.

[0015] According to a different aspect, the actuator is at least one of a motor or a hydraulic piston.

[0016] According to another aspect, the shaft includes teeth corresponding to teeth of a gear assembly such that rotation of the gear assembly causes the shaft to translate relative to the gear assembly.

[0017] According to yet another aspect, the at least one valve includes a first valve attached to the housing and exposed to the atmosphere and a second valve attached to the housing and exposed to an exhaust outlet.

[0018] According to a further aspect, the control unit is configured to modulate the first valve and the second valve to maintain an atmospheric pressure within the housing.

[0019] According to a different aspect, the at least one leg has three outer walls defining a cavity therebetween.

[0020] According to another aspect, a method of capturing emissions from an exhaust emitter comprises activating an actuator to translate a shaft relative to an adaptor; pivoting at least one leg operably coupled to the shaft to engage the exhaust emitter; sealing an emission capture device to the exhaust emitter by attaching a gasket of the adaptor to the exhaust emitter; sensing emission data from an inlet of a housing; and modulating a first valve operably coupled to a first outlet of the housing and a second valve operably coupled to a second outlet of the housing based on the emission data.

[0021] According to a further aspect, the step of sensing emission data includes sensing the emission data from a differential pressure sensor located in the housing.

[0022] According to another aspect, the step of modulating the first valve and second valve includes opening the first valve when the differential pressure sensor detects a non-zero value between an exhaust pressure and an atmospheric pressure.

[0023] According to a different aspect, the step of modulating the first valve and second valve includes opening the second valve and closing the first valve when the differential pressure sensor detects a zero valve between an exhaust pressure and an atmospheric pressure.

[0024] According to another aspect, the method further comprises positioning the emission capture device over the funnel with a robotic arm.

[0025] According to a different aspect, the step of modulating the first valve and second valve includes maintaining a constant temperature within the housing.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. **1** is a perspective view of an emission capture device, according to one embodiment of the disclosure.

[0027] FIG. **2** is a perspective view of the emission capture device of FIG. **1** attached to a robotic arm and an outlet duct.

[0028] FIG. **3** is an exploded perspective view of the emission capture device, robotic arm, and outlet duct of FIG. **2**.

[0029] FIG. **4** is a bottom view of the emission capture device of FIG. **1**.

[0030] FIG. **5** is a front view of the emission capture device of FIG. **1**.

[0031] FIG. **6** is a side cut-away view of the emission capture device, robotic arm, and outlet duct of FIG. **2**.

[0032] FIG. **7** is an enhanced view of a lower portion of emission capture device of FIG. **1**.

[0033] FIG. **8** is an enhanced view of internal components of the emission capture device of FIG. **1**.

[0034] FIG. **9** is another enhanced view of internal components of the emission capture device of FIG. **1**.

[0035] FIG. **10** is a control schematic of the control unit of the emission capture device of FIG. **1**.

[0036] FIG. **11** is a perspective view of emission capture device of FIG. **1** resting over a funnel with the legs contracted.

[0037] FIG. **12** is a perspective view of emission capture device of FIG. **1** resting over a funnel with the legs expanded.

[0038] FIG. **13** is a perspective view of a barge housing a treatment system configured to be implemented with the emission capture device of FIG. **1**.

[0039] FIG. **14** is a perspective view of the emission capture device of FIG. **1** being implemented with an industrial chimney.

DETAILED DESCRIPTION

[0040] The measurements, values, shapes and geometric references (such as perpendicularity and parallelism) in this document, when coupled with words such as “approximately” or similar terms, such as “nearly” or “substantially”, are to be understood as acknowledging measurement errors or inaccuracies due to production and/or manufacturing errors and, above all, minor variations from the associated value, measurement, shape or geometric reference. When these terms are associated with a value, for instance, they preferably indicate a variation of no more than 10% of the value. When terms such as “first”, “second”, “superior”, “inferior”, “main” and “secondary” are used, furthermore, they do not necessarily indicate an order, a relationship of priority or a relative position, but may be used simply to clarify the distinction between different components. Further, the term “inflow” generally refers to a direction toward the ship's stacks and the term “outflow” generally refers to a direction away from the ship's stacks.

[0041] FIG. **1** illustrates an emission capture device **10** according to one embodiment of the disclosure. Although the emission capture device **10** depicted and described herein is used in the shipping industry for fuel-dependent ships around or near harbors, it is envisioned that the emission capture device **10** could also be utilized with other emission producing devices on both land and water including but not limited to power plants, automobiles, long haul freight, trains, airplanes, and the like.

[0042] Emission capture device **10** includes a housing **12**. As depicted, housing **12** is configured in

a T-shape including an inlet **16** and two outlets **18**, **20**; however, other housing configurations, such as a spherical housing with a plurality of inlets and a plurality of outlets are envisioned. Inlet **16** is configured to attach to a stack of a vessel, hereinafter referred to as a funnel **14**. First outlet **18** extends approximately 90° from inlet **16** and guides exhaust from funnel **14** toward the treatment station **22**. Second outlet **20** extends approximately 180° from inlet **16** and approximately 90° from first outlet **18**. Second outlet **20** is a release outlet configured to release exhaust directly to the atmosphere. A series of valves described herein control the flow of exhaust from inlet **16** to first and second outlets **18**, **20**. Housing **12** is preferably a monolithic piece to avoid the possibility of exhaust escaping through a gap where the individual pieces are coupled. Further, although housing **12** is depicted herein in a T-shape with an inlet and outlets positioned approximately 90° from each other, it is envisioned that housings of other orientations, such as a housing with side outlet elbows extending 90° from each other in the same plane and an inlet positioned 90° from the elbows but in a separate plane, can be implemented with emission capture device **10**.
[0043] Housing **12** includes a mounting portion **24** in which a robotic arm **28** can attach to housing **12** and manipulate it to align with funnel **14**. Mounting portion includes a flat surface in which an interlocking port **26** can securely attach to. Mounting portion **24** is preferably monolithically formed with housing **12** to limit the possibility of gaps in the system where exhaust could escape to the atmosphere. Interlocking port **26** is attachable to both mounting portion **24** and a distal end of robotic arm **28**. Interlocking port **26** may be attached to mounting portion **24** by inserting fasteners (not shown) through attachment holes **30** into the flat surface of mounting portion **24**. Alternatively, interlocking port **26** may be monolithically formed with housing **12**. Interlocking port **26** includes an arm receiver **32** in which a distal end of robotic arm **28** attaches to. The arm receiver **32** depicted in FIG. **1** is substantially concave, although different shaped receivers are envisioned. Within arm receiver **32** is a pin attachment device **34** configured to receive and engage with an interlocking pin **36** extending from a tip mount **38** of robotic arm **28**. Interlocking pin **36** acts as the robotic arm's sixth axis of movement and allows the emission capture device **10** to be rotated around the end of robotic arm **28**. Pin attachment device **34** may be dimensioned to complement various interlocking pins depending on the type of of the robotic arm **28** implemented.
[0044] Robotic arm **28** may be any robotic arm known in the art that is configured to move along six axes. A six-axis robot allows the arm **50** to move in each of the x, y, and z planes and also to perform roll, pitch, and yaw movements. Thus, a six-axis robot closely mimics a human arm and would allow for ideal placement of emission capture device **10** on top of funnel **14**. Notably, interlocking pin **36** of robotic arm **28**, which provides the sixth axis of movement, is configured to extend into pin attachment device **34** to rotatably lock in place and allow for rotation in a direction similar to the direction of a human' s wrist rotation. Further, the tip mount **38** attaches direction to interlocking port **26**, which allows for the robotic arm's fifth axis of movement of pitch and yaw.
[0045] An interchangeable adaptor **40** depicted in FIGS. **1-3** is attachable to first inlet **16** of housing **12**. A primary purpose of adaptor **40** is that it may be the only interchangeable part of emission capture device **10** for fitting on different size funnels **14**. Thus, a single housing **12** and its internal components and control systems can be implemented for any funnel **14**, and only adaptor **40** needs to be swapped for certain funnels. As depicted, adaptor **40** is substantially cylindrical with a rigid body **42** and a rim **44**. Body **42** has an outer diameter than is smaller than an inner diameter of inlet **16** of housing **12**. This allows adaptor **40** to be inserted into inlet **16**. Further, the outer diameter of body **42** is dimensioned in a manner that produces an airtight fit, or close to an airtight fit, when inserted into inlet **16** to prevent exhaust from escaping. An O-ring or other type of sealant may be placed around body **42** to ensure an airtight fit between adaptor **40** and inlet **16**. Rim **44** extends around the circumference of a bottom portion of body **42** and extends radially outward to a dimension greater than the diameter of funnel **14**. Thus, rim **44** can have an inner diameter that is different than the inner diameter of body **42**, which in turns allows an operator to select different adapters for different size funnels. Alternatively, rim **44** can extend outward from body **42** in a non-

circular manner to match the shape of a funnel that is elliptical, square, or another shape. Similar to housing **12**, adaptor **40** is preferably monolithically constructed to prevent the possibility of gaps and subsequent air leaks.

[0046] As illustrated in FIG. **4**, rim **44** includes a gasket **150** on its underside configured to create a hermetic seal between funnel **14** and adaptor **40**. In such a manner, the gasket can be circular, elliptical, square, or another shape to match the shape of funnel **14**. Gasket **150** may be formed from any material known in the art that is capable of withstanding the high temperature of the exhaust leaving a vessel's diesel engine. These materials can include graphite, ceramic composites, other high-temperature fibers, certain metals, or combinations thereof. Gasket **150** is optimized to create a hermetic seal that maintains a constant exhaust temperature between funnel **14** and housing **12**. This constant temperature improves the efficiency of the abatement process and can also include the benefit of generating power that is harnessed for additional and secondary processes such as CO**2** capturing, desorbing, and storage.

[0047] A latch mechanism **46** is implemented to secure adaptor **40** to inlet **16** of housing **12**. Latch mechanism **46** may extend from a bottom rim **44** of housing **12** adjacent inlet **16**. Latch mechanism **46** may include a base plate **48**, arm **50**, and hinge portion **52**. Base plate **48** may attach to rim **44** using fasteners or other attachment types and extend downwards past rim **44**. A receiving plate **54** is attached to body **42** of adaptor **40** and has a hook **56** for securely engaging arm **50**. Receiving plate **54** may attach to body **42** of adaptor **40** with fasteners or other attachment types known in the art. In use, an operator or robot can grasp hinge portion **52** to loosen it and allow arm **50** to extend towards adaptor **40**. Once arm **50** is securely engaged with hook **56**, hinge portion **52** can be clamped downward to lock latch mechanism **46** in place. The same process can be repeated in reverse steps to unlatch latch mechanism **46**. Alternatively, other latching mechanism known in the art may be utilized to secure adaptor **40** to housing **12** such as buckles, pressure fits, fasteners, or the like.

[0048] FIGS. **6-8** depict a leg assembly **58** used to secure emission capture device **10** to funnel **14**. Leg assembly **58** includes a plurality of legs **60** surrounding and rotatably attached to a shaft **62**. However, in alternative embodiments, a single leg or a plurality of legs may be implemented with leg assembly **58**. Shaft **62** is slidably attached to adaptor **40** and housing **12** via a series of supports **64**. Shaft limits **66** act as stoppers to prevent shaft **62** from sliding through support **64**. At an upper end, teeth formed in a portion of shaft **62** engage with corresponding teeth of gear **68** located on gear assembly **70**. gear assembly **70** includes an output shaft **62**, at least one gear **68**, and a motor **74** configured to turn output shaft **62**. Each of these components will be described in greater detail herein.

[0049] Each leg **60** of leg assembly **58** extends along a longitudinal axis and has three outer walls **76** that substantially form a U-shape defining a cavity **84** in the center. Thus, each of the three walls **76** of legs **60** defines a thickness **78** and the thickness **78** of each of the three outer walls **76** may be substantially uniform. This design is advantageous as it allows for exhaust to flow through legs **60** when legs are secured around funnel **14**, rather than blocking flow of exhaust through inlet **16**. If the flow of exhaust were blocked, it could cause the system pressure to increase, which could result in a more inefficient capture of emissions, or even backpressure sent through funnel **14**. This can be illustrated with Bernoulli's principle, which holds that an increase in a fluid's speed is accompanied by a decrease in the fluid's pressure. Applied to this system, if legs **60** were rectangular prisms and did not permit airflow to pass therethrough, the resulting system pressure would increase and make it more difficult to properly divert the exhaust through valves to treatment station **22**.

[0050] Legs **60** extend from an upper portion **80** to a lower portion **82**. The upper portion **80** defines an attachment feature **86** for attaching the leg to support **64**. Attachment feature **86** may be a hook as shown in FIG. **6**, or another attachment feature such as a slot, hinge, or the like. A connecting rod **88** extends from and is rotatably attached to cavity **84** and is configured to attach to a pivot point **90** located on either shaft **62**, support **64**, or shaft limit **66**. In such a configuration, connecting rod **88** is pivotable with respect to both legs **60** and shaft **62** and causes lower portion **82** of legs **60** to extend radially outward away from shaft **62** to attach to the inside of funnel **14**. Connecting rod **88** may be a rigid rod as depicted, or it could also be a spring configured to bias legs **60** radially outward away from shaft **62**. The spring embodiment may be advantageous as the biasing force would secure adaptor **40** to funnel **14**. Even if connector rod **88** is rigid, a spring or other form of biasing element may be placed at another location along the length of leg **60** to bias leg **60** radially outward away from shaft **62**.

[0051] Lower portion **82** of legs **60** includes a spring **152** configured to aid in attaching adaptor **40** to the inside of funnel **14**. Spring **152** may be any spring known in the art, such as a harmonic steel spring or the like. When leg **60** is biased outward from shaft **62** via connecting rod **88** or via another biasing element, spring **152** contacts the inner surface of funnel **14** and causes a force that pushes the lower portion **82** of leg **60** away from the inner surface of funnel **14**. Thus, in such a configuration, the legs **60** cause a pushing force into the inner funnel wall and the springs cause an opposed force directed back toward shaft **62**. This force is configured to maintain an equilibrium which secures adaptor **40** to funnel **14** until a release is pressed to move legs **60** radially inward. This force equilibrium, in conjunction with gasket **150** forming a hermetic seal between adaptor **40** and funnel **14**, allows for a hermetic seal to be formed. Although the embodiment depicted in FIGS. **1-8** shows six legs **60**, a different number of legs, such as a single leg or two legs, may be implemented. Further, other attachment mechanisms than legs may be implemented. For example, a gripper with a set of jaws (not shown) may be implemented to attach to an outer rim of funnel **14**.

[0052] FIG. **8** depicts a support **64** according to one embodiment. Support **64** is substantially circular to fit snugly within adaptor **40**. Support **64** has an outer rim **92** extending around a hub **94**. At least one arm **50** extends radially outward from hub **94** to a point past outer rim **44**. Outer rim **92** may include a hole through which arm **50** extends. A brace **98** is located at the end of arm **50** opposite hub **94** and is configured to brace against the side of either adaptor **40** or housing **12**. Brace **98** may attach to arm **50** via a pressure fit of arm **50** within a cradle portion (not shown) of brace **98**, or with fasteners or other attachment types known in the art. Arm **50** may attach to hub **94** using similar attachment methods. Hub **94** is cannulated to allow shaft **62** to pass therethrough. In such a configuration, the inner diameter of hub **94** is preferably larger than an outer diameter of shaft **62**. Although the embodiment depicted shows two supports **64**, it is envisioned that any number of supports **64** may be utilized to secure leg assembly **58** to housing **12**. Various ledges (not shown) may be placed around the inner diameter of adaptor **40** and inlet **16** of housing **12** to allow support **64** to rest on the ledge without being pulled lower from the weight of the legs **60**.

[0053] Shaft limits **66** are also generally circular and cannulated to accept shaft **62**. Shaft limits **66** may have a key **100** to accept a toothed portion **104** of shaft **62**. In such a manner, shaft **62** may only be slid through shaft limit **66** in one orientation such that a toothed portion **104** of shaft aligns with key **100**. A similar key **100** may be integrated with support **64**. Unlike support **64**, shaft limit **66** is securely fastened to shaft **62** to act as a stopper. Thus, as shaft **62** translates up and down, shaft limit **66** translates with shaft **62** and prevents movement of shaft **62** when it contacts an adjacent support **64**. Supports **64** can therefore be set at various heights within adaptor **40** to set a preferred range of motion for legs **60**.

[0054] FIG. **8** illustrates a shaft **62** according to one embodiment. Shaft **62** extends along a longitudinal axis and includes a column **102** and a toothed portion **104**. Column **102** is substantially cylindrical and preferably has a smooth outer surface to facilitate translation of shaft **62** through support **64**. The diameter of shaft **62** is dimensioned to fit within the cannulated portion of support **64** and shaft limit **66**. A toothed portion **104** extends radially outward from column **102** at one point around the circumference of column **102**. In such a manner, shaft **62** does not have a true circular cross-section, but rather has a semi-circular cross-section with a keyed portion extending away from the non-circular portion. Thus, shaft **62** may only extend through support **64** and shaft limit **66** in one rotational orientation.

[0055] Toothed portion **104** is configured to mate with teeth of a gear **68** of gear assembly **70**. When engaged, rotation of gear **68** causes shaft **62** to translate either up or down along its longitudinal axis, i.e., along the same direction of toothed portion **104**. This gearing mechanism acts as a ratchet mechanism that allows for translation of shaft **62** in a single direction. In this embodiment, a pawl (not shown) may be rotatably attached to gear assembly **70** and spring-loaded in a manner that biases the pawl to extend toward gear **68** so that it can extend into the recesses between the gear teeth. As gear **68** rotates and causes toothed portion **104** to translate, the pawl may contact either toothed portion **104** or gear **68** to prevent either translation or rotation in the opposite direction. For example, rotation of gear **68** in a first clockwise direction may cause shaft **62** to translate downward, which in turns opens legs **60**. To translate shaft **62** upward to close legs **60**, a pawl release (not shown) may be actuated to disengage pawl from either gear **68** or toothed portion **104** to allow rotation of gear **68** in the opposite direction to raise shaft **62**. Although the example previously described involves clockwise rotation of gear **68** to open legs **60**, it is envisioned that counterclockwise rotation could also be utilized to open legs **60**. In other embodiments, different mechanisms than a pawl may be implemented to prevent translation of shaft **62** in a certain direction.

[0056] Toothed portion **104** may include a series of teeth spaced linearly along the longitudinal axis of shaft **62**. Further, toothed portion **104** may be dimensioned to correspond with the teeth of gear **68**, such that rotation of gear **68** causes translation of shaft **62**. In doing so, the teeth of gear **68** (not shown) may extend into corresponding roots of toothed portion **104** and vice versa, thus allowing shaft **62** and gear assembly **70** to be rotatably coupled together. Toothed portion **104** may be considered a belt, rack, or other linear gear system configured to engage with a circular gear such as a pinion or worm gear.

[0057] FIG. **6** illustrates a preferred embodiment of a gear assembly **70** that includes a gear **68**, rotation shaft **62**, and motor **74**. Motor **74** may attach to an outer surface of housing **12** or may be internally mounted in a protective cage to ensure exhaust gases do not cause damage. Motor **74** may be any standard motor known in the art, such as an AC brushless or DC brushed motor. A battery (not shown) may be attached to an external surface of housing **12** to power motor **74**. In another embodiment, motor **74** may be powered through renewable energy sources. Because the emission capture device **10** is utilized outdoors in port cities that may have few obstructions, renewable sources like solar or wind may be utilized instead of or in conjunction with a battery to power motor **74** or other electronic devices within emission capture device **10**. Solar panels (not shown) may be affixed to an outer surface of housing **12** or to another vessel in which emission capture device **10** is attached. Alternatively, wind-harnessing devices such as wind turbines may be placed on top of housing **12** or on vessel to harness the wind flowing around and through harbors. In either of these embodiments, a hard-wired connection may exist between the energy source and the motor. A visual indicator may be located on a surface of housing **12** to show an operator the remaining battery life available. The visual indicator may be a series of light emitting diodes (LED) configured to change color or turn off entirely as the battery charge is diminished. Alternatively, in other embodiments, another type of actuator such as a hydraulic piston may be implemented in place of gear assembly **70** to engage a leg assembly with a funnel.

[0058] Motor **74** outputs a rotational force on output shaft **62**. Output shaft **62** extends from motor **74** inside housing **12** to at least a first gear **68**. Gear **68** may be rotatably coupled to output shaft **62** via a collar or other coupling device known in the art. Gear **68** may be a rack gear configured to translate on a pinion of toothed portion **104** of shaft **62**. In other embodiments with a 90° angle between rotation shaft **62** and shaft **62**, other gears such as bevels, worms, or the like may be utilized. In embodiments where a 90° angle is not feasible, gear **68** may be a crossed helical gear, certain bevels, and the like. As described herein, gear **68** has teeth configured to mate with corresponding teeth of toothed portion **104** of shaft **62**. The teeth (not shown) may be straight or curved depending on the type of gear utilized. Further, multiple gears may be placed along rotation

shaft **62** in embodiments where multiple gears are required to translate shaft **62** or due to a unique geometry of housing **12**. Various sensors may be coupled to gear assembly **70** to track characteristics such as rotations per minute (rpm) of rotation shaft and direction of rotation. Such sensors may be part of a leg control unit **108** that may also house motor **74** and/or a battery. Leg control unit **108** may be coupled to the outside of housing **12** using fasteners, adhesives, or the like.
[0059] Housing **12** includes second outlet **20** located opposite inlet **16** and configured to allow an escape for exhaust to flow out of emission capture device **10** directly into the atmosphere. Exhaust may be diverted through housing **12** through a series of valves, one of which being a modulating top valve **110**. Modulating top valve **110** is configured to raise and lower a valve top **112** to sealably cover second outlet **20**. Valve top **112** may be coupled to emission capture device **10** by an actuator **114** and a connecting rod **116** and be operated by a control unit **118**, each component described in further detail below.
[0060] FIGS. **5-6** illustrates valve top **112** according to one embodiment. Valve top **112** is generally frustoconical with a continuous conical surface **120** defined between two flat surfaces, each of the two flat surfaces corresponding to a top and bottom surface **122**, **124** of valve top **112**. The diameter of second outlet **20** is preferably larger than the diameter of bottom surface **124**, but smaller than the diameter of top surface **122**. In such a configuration, the conical surface **120** of valve top **112** may act as a hermetic seal with second outlet **20** to prevent exhaust from escaping into the atmosphere while valve top **112** is closed.
[0061] Valve top **112** translates up and down along a post **126**. Post **126** may be cylindrical and have a stopper **128** at its lower end to abut the bottom surface **124** of valve top **112** to raise it. The weight of valve top **112** may lower it over second outlet **20** without the need for actuation of post **126**. Alternatively, valve top **112** may only be lowered by actuation of post **126**. Post **126** extends through a hole formed entirely through valve top **112** and centrally positioned through top surface **122** and bottom surface **124**. Thus, when post **126** is raised so that stopper **128** contacts bottom surface **124**, a uniform force lifts valve top **112** entirely off second outlet **20** without tilting or causing an uneven lifting force.
[0062] The top of post **126** has a hook portion **130** configured to engage with a first end **134** of a connecting rod **116**. A pin (not shown) may be inserted through a hole in the hook portion **130** that aligns with a hole in first end **134** of connecting rod **116**. Other hinge types known in the art may also be utilized in place of a pin being inserted through a hole. Connecting rod **116** extends from first end **134** to second end **136**. Connecting rod **116** may be a cylindrical rod extending between first end **134** and second end **136**, each of first and second ends **134**, **136** being U-shaped to fit around hook portion **130** and a connecting portion of an actuator **114**. However, other foreseeable connecting rod designs may be implemented without departing from the spirit of the present disclosure.
[0063] Actuator **114** is configured to transmit a vertical force to connecting rod **116**, which in turn raises valve top **112**. Actuator **114** may be a hydraulic actuator, such as a piston, with an outer sleeve surrounding an inner sleeve. A hydraulic system (not shown) with a fluid reservoir and at least one pump may allow for the vertical translation of the inner sleeve relative to the outer sleeve. Alternatively, other types of actuators may be implemented, such as pneumatics, electric actuators, or the like. An upper portion of actuator **114** may include a connecting portion **132** configured to engage with second end **136** of connecting rod **116**. This connection may be facilitated by a pin inserted through a hole or another connection type known in the art. Actuator **114** may extend through a guide (not shown) positioned on housing **12** to align it with a control unit **118**.
[0064] Actuator **114** may include a wired connection **138** to control unit **118**. Control unit **118** may be a standard control unit known in the art and preferably has at least the capabilities of receiving user inputs, receiving inputs from the various sensors described herein and positioned throughout emission capture device **10**, modulating the valves to direct the flow of exhaust, controlling the expansion and contraction of legs **60**, and communicating with a user interface within the treatment

station **22**.

[0065] Control unit **118** may be any type of control unit known in the art, such as an electronic control unit (ECU) or the like. Control unit **118** preferably includes a microcontroller and a memory system such as ROM, RAM, or the like. The microcontroller may be a standard microcontroller known in the art and may include a central processing unit (CPU) configured to read inputs, perform calculations based on the inputs, and determine outputs. Control unit **118** is configured to communicate with various sensors and valves throughout emission capture device **10** via wired connection **138**. Wired connection **138** may be a communication link, such as a bus transceiver or the like. Wired connection **138** may further link a battery (not shown) to control unit **118** to provide power thereto.

[0066] Control unit **118** may further be configured to receive embedded software therein. An operator may input software programs directly to control unit **118** via a computer system **140** located within treatment station system **22**. These software programs may, for example, correspond to different size ships, ships operating with different fuel types, or different exhaust capture methods. For example, one software program may be configured to operate emission capture device **10** in conjunction with a mainstream cruise ship, and another software program may be configured to operate emission capture device **10** in conjunction with an ultra-large container ship. Alternatively, one software program may allow an operator to select the type of vessel that emission capture device **10** is attaching to so that multiple software programs are not required. Regardless of the software program utilized, computer system **140** may communicate with control unit **118** via a hard-wired communication link such as a bus transceiver.

[0067] One of the primary purposes of emission capture device **10** is to create a hermetic seal around a funnel of a vessel and divert the exhaust flow through a series of valves so that it flows to a treatment station where it is converted into a powder rather than escaping to the atmosphere. A schematic reference for this method is illustrated in FIG. **10**. Notably, FIG. **10** depicts a schematic in which emission capture device **10** is already attached to funnel **14**. In an initial step, exhaust flows out of a stack or funnel **14** toward inlet **16**. From the housing **12**, the exhaust can flow in one of two directions. First, the exhaust can flow toward valve top **112** which opens directly to the atmosphere. Alternatively, the exhaust can flow toward second valve **142** which diverts the exhaust toward treatment station **22**.

[0068] To determine whether valve top **112** and/or second valve **142** should be opened or closed, a sensor system **144** is implemented in emission capture device **10**. Sensor system **144** includes a first sensor **144** located at inlet **16** of housing **12**. First sensor **144** is preferably a differential pressure sensor configured to monitor the pressure change between funnel **14** and housing **12** and communicate that change to control unit **118**. First sensor **144** may be internally mounted within housing **12** using fasteners, adhesives, clips, or the like. Preferably, emission capture device **10** maintains the same pressure within housing **12** as the exhaust pressure exiting funnel **14**. With a constant pressure, the system will minimize the chance for backflow of exhaust to flow back through funnel **14** and potentially damage the vessel's engines. Furthermore, maintaining a constant pressure in the system allows for an easier conversion of exhaust to powder or another disposable substance within treatment station **22**. In addition to a first differential pressure sensor, other sensor types such as temperature, air speed temperature, and the like may be implemented in emission capture device **10**. Particularly, temperature sensors may be implemented to ensure gasket **150** is maintaining a constant temperature between funnel **14** and housing **12**.

[0069] An output signal from first sensor **144** is transmitted to control unit **118**. Control unit **118** is configured to receive the output signal and based on a provided software system, send a signal to first and/or second valve **110**, **142** to open or close the valve. Examples of these controls are provided below. Control unit **118** includes a memory system, a variable frequency device **148** configured to modulate the frequency and voltage supplied to a motor which in turn opens and closes first and second valves **110**, **142**.

[0070] Various fans may be placed throughout emission capture device **10**. The fans (not shown) are configured to push or pull exhaust in a targeted direction within housing **12**. For example, a fan located adjacent to valve top **112** may draw exhaust at a greater speed toward valve top **112** in an event where the pressure within housing **12** exceeds the atmospheric pressure and the exhaust needs to rapidly be released to prevent backpressure. Alternatively, the fans may be configured to draw air towards outlet duct **154** if the pressure within the release duct is lower than the pressure within housing **12**.

[0071] A method of using emission capture device **10** is provided herein. As explained herein, emission capture device **10** may be utilized with exhaust producing devices on land and in the water. The method described herein continues to describe emission capture device **10** in conjunction with a ship having an exhaust-producing funnel. As an initial step, a barge **158** or other vessel holding emission capture device **10** may approach a target vessel having an exhaust-producing funnel **14**.

[0072] A user may then use a computer system **140** located on barge **158** that is configured to operate emission capture device **10**. Computer system **140** is configured to interact with control unit **118** to control the flow of exhaust from funnel **14** to treatment station **22**. A user may select a setting that corresponds to the type of ship that emission capture device **10** will attach to. For example, a user may select an ultra-large container ship setting that corresponds to the pressures, temperatures, emission type, and other various settings that an ultra-large container ship produces. The software program may then suggest an adaptor **40** that is configured to attach to a specific funnel of the ultra-large container ship. An operator may then use latch mechanism **46** to secure the required adaptor **40** to housing **12** of emission capture device **10**. An O-ring or other sealant may ensure a hermetic seal exists between adaptor **40** and housing **12** such that exhaust cannot escape to the atmosphere.

[0073] As shown in FIG. **13**, once the barge **158** is in a sufficient location and the appropriate adaptor **40** has been attached to housing **12**, a user can operate a crane in conjunction with a robot to maneuver a robotic arm **28** connected to an interlocking port **26** of an emission capture device **10** toward exhaust funnel **14**. Because the robot is preferably a six-axis robot, an operator can maneuver emission capture device in a manner where adaptor **40** is coaxial with and aligned directly above funnel **14**. For a ship in which funnel **14** does not extend vertically, the adapter may be positioned coaxial with and direction in front of the opening of funnel **14**.

[0074] An operator may then guide adaptor **40** over the opening of funnel **14** such that gasket **150** of rim **44** creates a hermetic seal between adaptor **40** and funnel **14**. To determine if a hermetic seal has been fully formed between funnel **14** and adaptor **40**, emission capture device **10** may be equipped with a series of cameras (not shown) located on housing **12**, robotic arm **28**, or adaptor **40**. The cameras provide live footage to a user interface of computer system **140** so that an operator may see if adaptor **40** has been attached. Further, differential pressure sensor **146** may begin to immediately send a reading to control unit **118** and to computer system **140** to allow a user to see if the pressure within housing **12** has changed, which could signal whether a seal has been created.

[0075] Once the hermetic seal has been created, leg control unit **108** may be operated either automatically or based on an input from a user in the computer system **140**. This input will direct motor **74** to turn output shaft **62** and gear **68**, which in turn causes shaft **62** to translate along its longitudinal axis as the teeth of gear **68** engage with corresponding recesses of toothed portion **104** of shaft **62**. As shaft **62** translates down through at least one support **64**, shaft limit **66** will contact support **64** which in turn flairs connecting rod **88** outward to push a lower portion of leg **60** away from shaft **62**. A spring or other type of biasing element may also be implemented to push leg **60** away from shaft **62** as shaft **62** is lowered. Spring **152** on the end of leg **60** may contact an inner surface of funnel **14** to provide an opposite force that counteracts the force of the leg pushing into the wall. This force equilibrium securely holds emission capture device **10** to funnel **14**.

[0076] Once the adapter is sealed and secured to funnel **14**, robotic arm **28** may be removed from emission capture device **10** until the emission capture device **10** is ready to be removed from funnel **14**. Next, a user may initiate a control of computer system **140** that activates a control system that begins the capture of exhaust. Various sensors throughout the system, such as differential pressure sensor **146**, a temperature sensor, and other sensors mentioned herein may begin to record data and transmit that data to both control unit **118** and computer system **140**. An operator at computer system **140** may see these readings in real time while simultaneously viewing emission capture device through a variety of cameras or other imaging systems, such as a thermal imaging system, located on emission capture device **10**. Control unit **118** is configured to receive sensor data and determine outputs that divert the flow of exhaust to treatment station **22** on barge **158**. Notably, control unit **118** is configured to automatically operate emission capture device **10** without the need for user input. However, manual overrides throughout the system allow a user to at least open and close first and second valves **110**, **142** to activate motor **74** which causes legs **60** to expand and contract, and to activate and deactivate control unit **118** via computer system **140**. The legs **60** can be seen in contracted and expanded views in FIGS. **11** and **12**, respectively.

[0077] Under ideal operating conditions, the pressure within housing **12** is equal to the atmospheric pressure acting on housing **12**. Thus, differential pressure sensor **146** located at first valve **110** ideally will read a value of O as there is no change in pressure between funnel **14** and housing **12**. However, if differential pressure sensor **146** detects any change in pressure, such as a positive 0.3-inch change or a negative 0.3-inch change on a water gage, or a corresponding minute change in other units such as pounds per square inch (psi) or pascals (Pa), control unit **118** sends a signal to valve top **112** to open using actuator **114** and connecting rod **116**. Notably, valve top **112** is not a binary valve with only fully open and fully closed positions. Rather, it has many intermediate positions that allow for minute changes in pressure for differential pressure sensor **146** to detect no change in pressure between inflow pressure and atmospheric pressure.

[0078] Control unit **118** can modulate both first valve **110** and second valve **142** simultaneously. For example, if the pressure within housing **12** is greater than the atmospheric pressure and the potential for backpressure to travel down funnel **14** is imminent, control unit **118** could receive a pressure reading from differential pressure sensor **146** that has a positive value and partially close second valve **142** while partially opening first valve **110**. Thus, it is possible that neither valve is entirely opened nor entirely closed at any given point in time, and the valves can modulate in harmony to maintain a differential pressure reading of O within housing **12**.

[0079] Emission capture device **10** is configured to operate for a particular funnel the entire duration of a ship's stay in a harbor. Thus, barge **158** can track the movements of a ship to remain adjacent to it until the ship is ready to leave the harbor. Once the ship is ready to leave, an operator can remove emission capture device **10** using a sequence of steps that reverse the set of steps of attaching emission capture device **10**. First, valve top **112** may be opened during the entire deactivation procedure to allow the ship's exhaust to be released directly into the atmosphere without the potential for backpressure. Next, robotic arm **28** may reattach to interlocking port **26** of housing **12** if it had been previously detached. Then, a user may operate a control that causes motor **74** to turn output shaft **62** in an opposite direction than what it turned to attach legs **60** to an inner surface of funnel **14**. This causes the lower portion **82** of legs **60** to pivot inward toward shaft **62** and away from the inner surface of funnel **14**. Finally, a user may operator robotic arm **28** to lift emission capture device **10** off and away from funnel **14**. Because emission capture device **10** has only a modular adapter, a user can then quickly swap out adapters to configure to another ship entering the harbor, and the entire process can be repeated.

[0080] Although the embodiment described herein relates to a single emission capture device **10** that attaches to a single funnel **14** of a ship, it is envisioned that multiple emission capture devices could be joined in series for a plurality of funnels of ships or of other emission-producing devices on land, such as smokestacks, industrial chimneys, and the like.

[0081] FIG. **14** depicts another embodiment of emission capture device **10** used in conjunction with an industrial chimney **160**. In such an embodiment, emission capture device **10** may be attached to an arm, such as robotic arm, a crane, or the like, to be maneuvered over chimney **160**. The arm holding emission capture device **10** may also be attached to a vehicle on wheels or treads, such as a truck or an excavator. The industrial chimney **160** may extend from a glass or metallurgical mill furnace, or other industrial furnace types that produce exhaust. The operation of emission capture device **10** is the same regardless of whether emission capture device **10** is implemented with a funnel **14** of a ship or an industrial chimney **160**.

[0082] The present disclosure may be embodied in other specific forms without departing from its spirit or characteristics. The described embodiments are to be considered as illustrative and not restrictive. The scope of the disclosure is, therefore, indicated by the appended claims rather than by the foregoing description. Changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims

1. A system of controlling the capture of emissions from an exhaust emitter comprising: a housing including an inlet, a first outlet, and a second outlet; an attachment assembly having a shaft, a motor, a gear assembly and an adapter configured to attach to the exhaust emitter and the inlet of the housing, the attachment assembly removably couplable to the adapter; at least one valve coupled to the housing and including a first valve located between the housing and the first outlet and a second valve located between the housing and the second outlet coupled to the housing; and a control unit capable of communicating with the at least one valve to control the emission of exhaust through the device, wherein the shaft includes teeth configured to mate with the gear of the gear assembly to operably couple the shaft to the motor.