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(54) **SYSTEMS FOR HUMAN WASTE COLLECTION AND PROCESSING**

(71) Applicant: **Hamilton Sundstrand Space Systems International, Inc.**, Windsor Locks, CT (US)

(72) Inventors: **Ashley Rose Himmelmann Schuster**, Chicago, IL (US); **Beakal Teshome Woldemariam**, South Windsor, CT (US); **Thao Hoang**, Arlington, WA (US); **Timothy Monson**, Winnebago, IL (US); **Kevin Litton**, Houston, TX (US); **Thomas Gay**, Enfield, CT (US); **Casey Myers**, Parker, CO (US); **Liana J. He**, West Hartford, CT (US)

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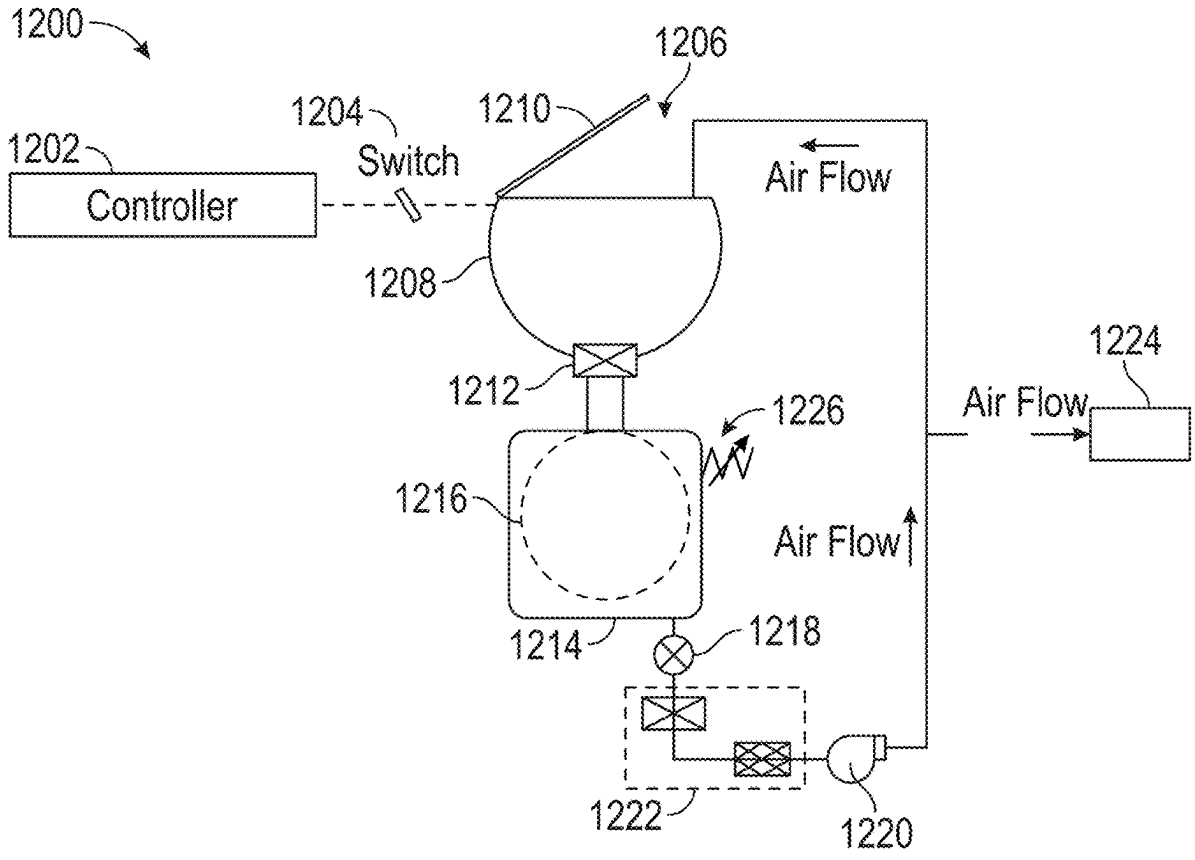
(57) **ABSTRACT**

Waste collection and processing systems for use in low-gravity environments include a toilet having a bowl and a lid with a waste tank having an inlet and an outlet, wherein the bowl of the toilet is fluidly coupled to the inlet of the waste tank. A waste bag is arranged within the waste tank to capture human waste deposited into the waste tank from the toilet bowl. The waste bag is permeable to gases and impermeable to liquid waste and solid waste. A filter assembly is fluidly coupled to the outlet of the waste tank and configured to treat air that passes through the filter assembly. A first valve is operably arranged between the bowl and the waste tank and a second valve is operably arranged between the waste tank and the filter assembly.



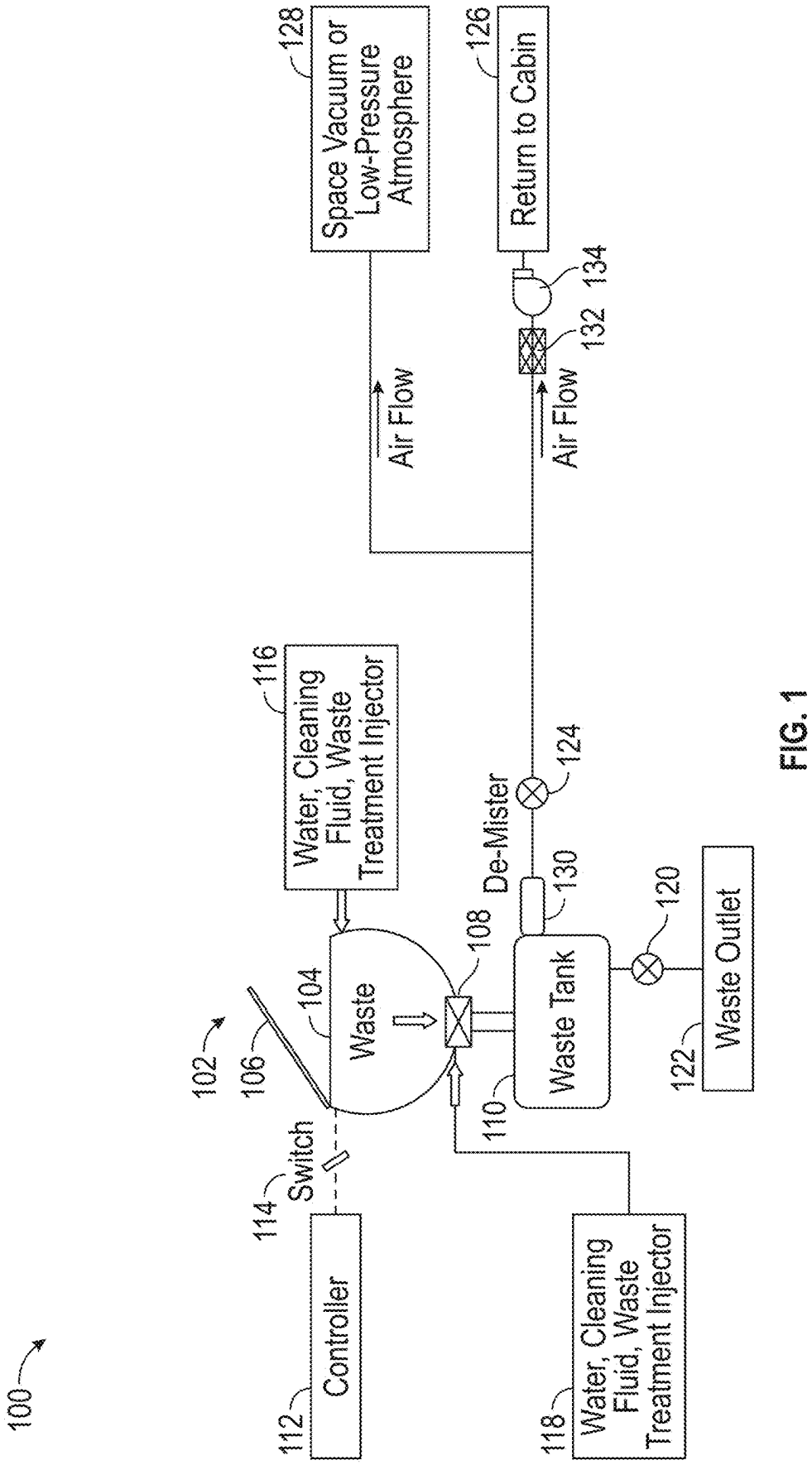

100
112
Controller
114
Switch
118
Water, Cleaning Fluid, Waste Treatment Injector
102
106
104
Waste
108
110
Waste Tank
120
122
Waste Outlet
De-Mister
130
124
116
Water, Cleaning Fluid, Waste Treatment Injector
Air Flow
Air Flow
132
134
126
Return to Cabin
128
Space Vacuum or Low-Pressure Atmosphere

FIG. 1

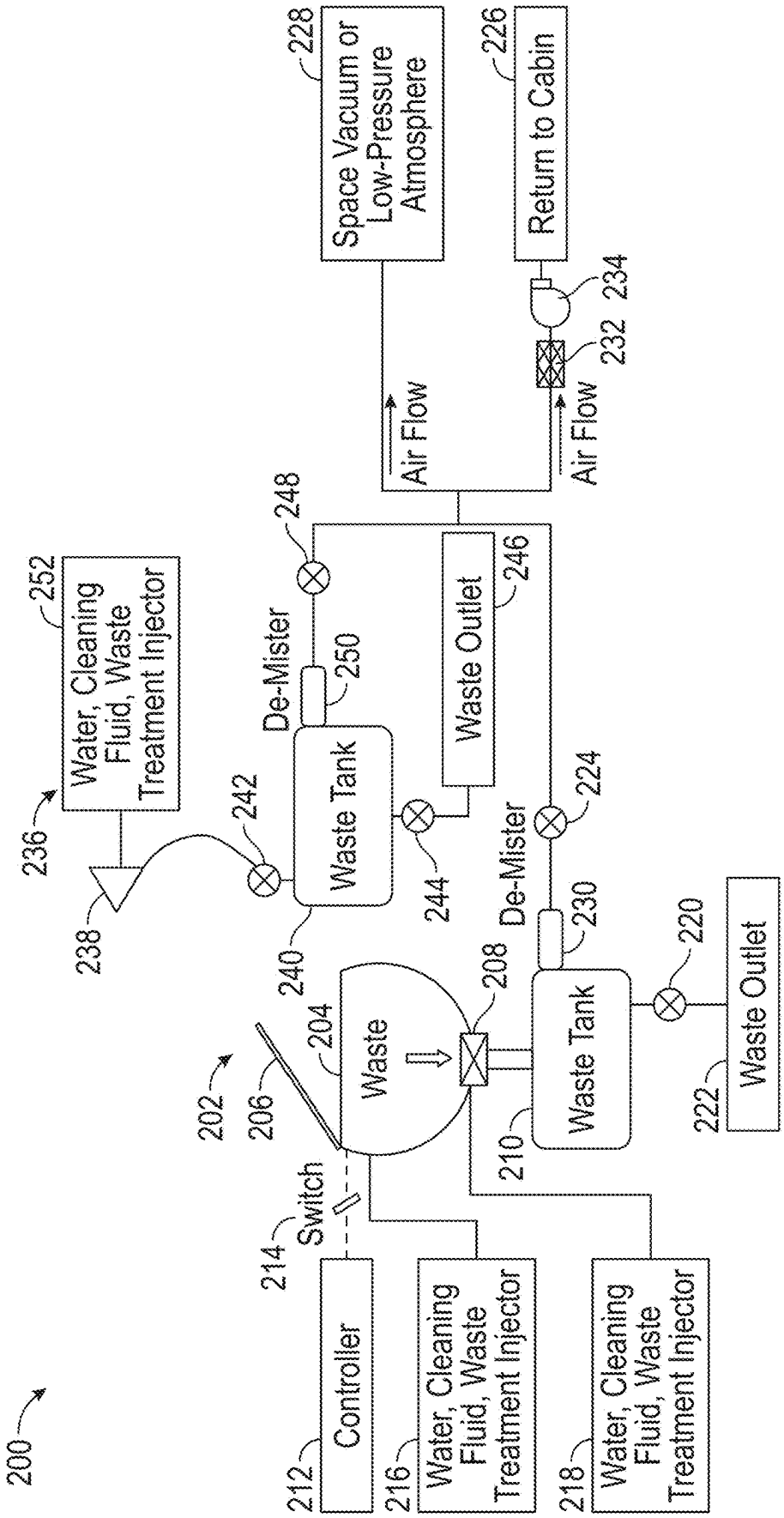

200
212
Controller
214
Switch
216
Water, Cleaning Fluid, Waste Treatment Injector
218
Water, Cleaning Fluid, Waste Treatment Injector
202
204
206
Waste
208
210
Waste Tank
220
Waste Outlet
222
De-Mister
230
224
De-Mister
240
242
Waste Tank
244
Waste Outlet
246
248
De-Mister
250
236
238
Water, Cleaning Fluid, Waste Treatment Injector
252
Air Flow
Air Flow
228
Space Vacuum or Low-Pressure Atmosphere
226
Return to Cabin
232
234

FIG. 2

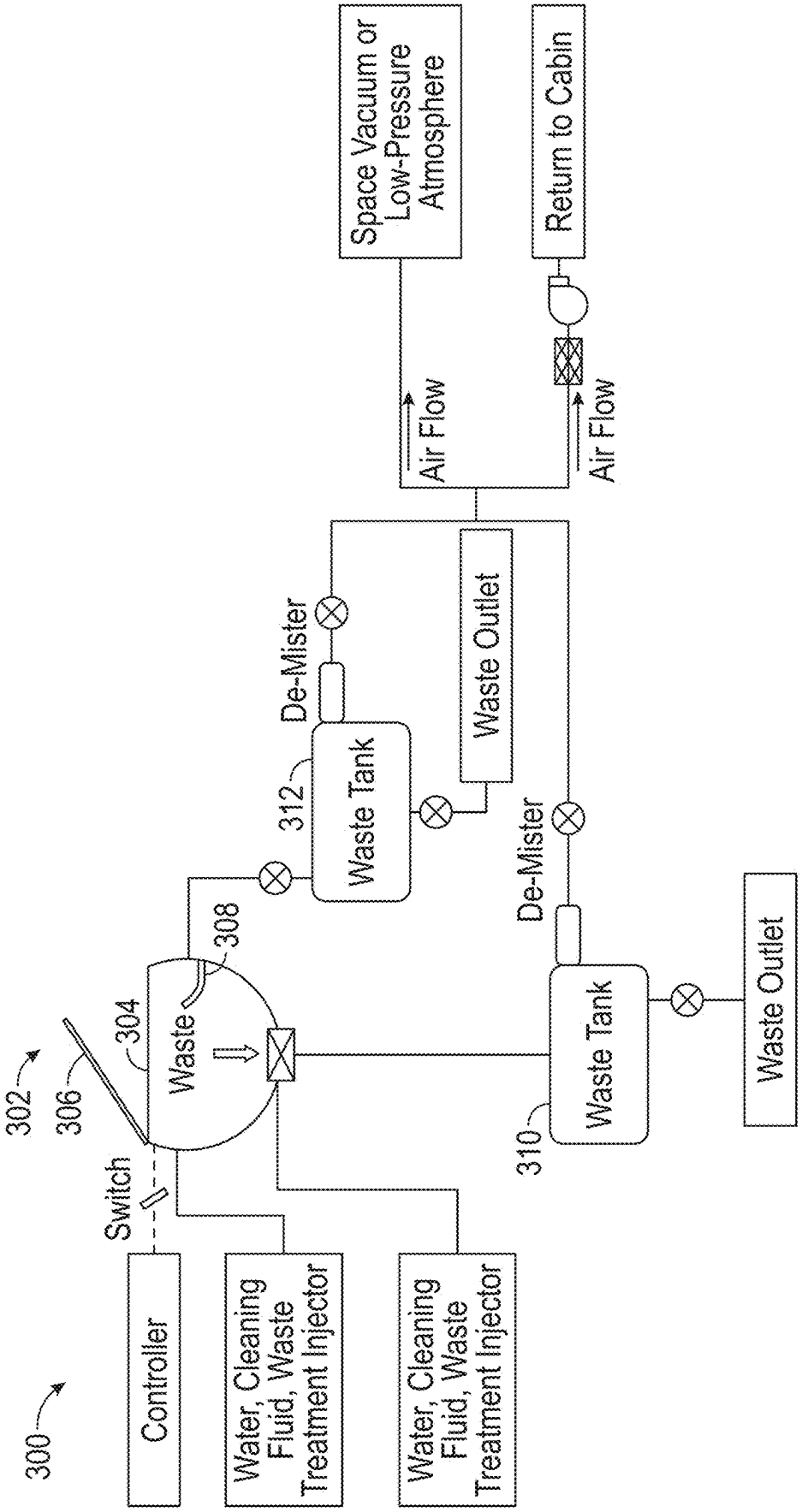

300
Controller
Water, Cleaning Fluid, Waste Treatment Injector
Water, Cleaning Fluid, Waste Treatment Injector
Switch
302
306
304
Waste
308
312
Waste Tank
De-Mister
Waste Outlet
De-Mister
310
Waste Tank
Waste Outlet
Air Flow
Air Flow
Space Vacuum or Low-Pressure Atmosphere
Return to Cabin

FIG. 3

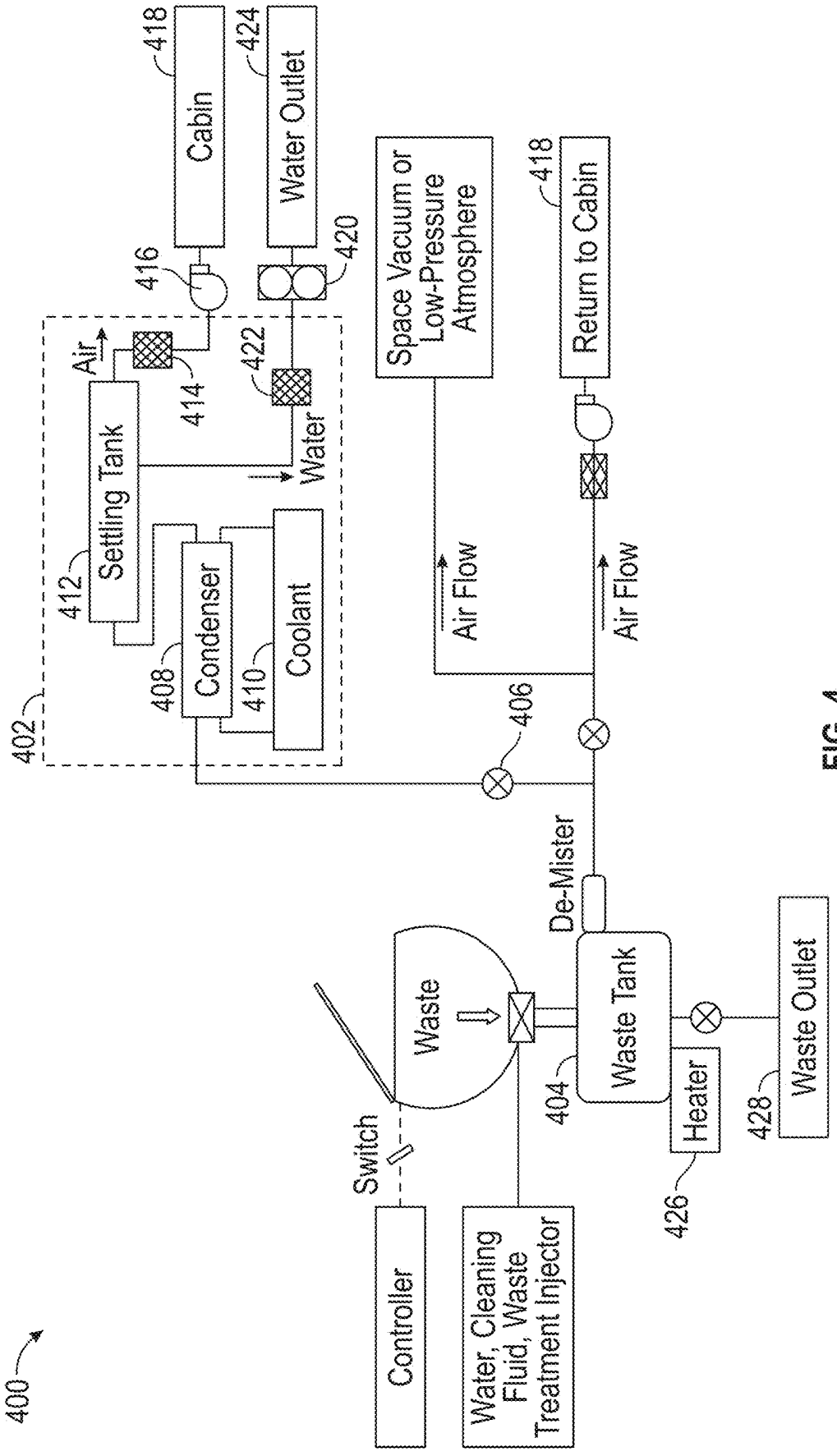

400
Controller
Switch
Water, Cleaning Fluid, Waste Treatment Injector
Waste
De-Mister
Waste Tank
404
Heater
426
Waste Outlet
428
406
402
Settling Tank
412
Condenser
408
Coolant
410
Air
414
Water
422
416
420
Cabin
418
Water Outlet
424
Space Vacuum or Low-Pressure Atmosphere
Air Flow
Return to Cabin
418
Air Flow

FIG. 4

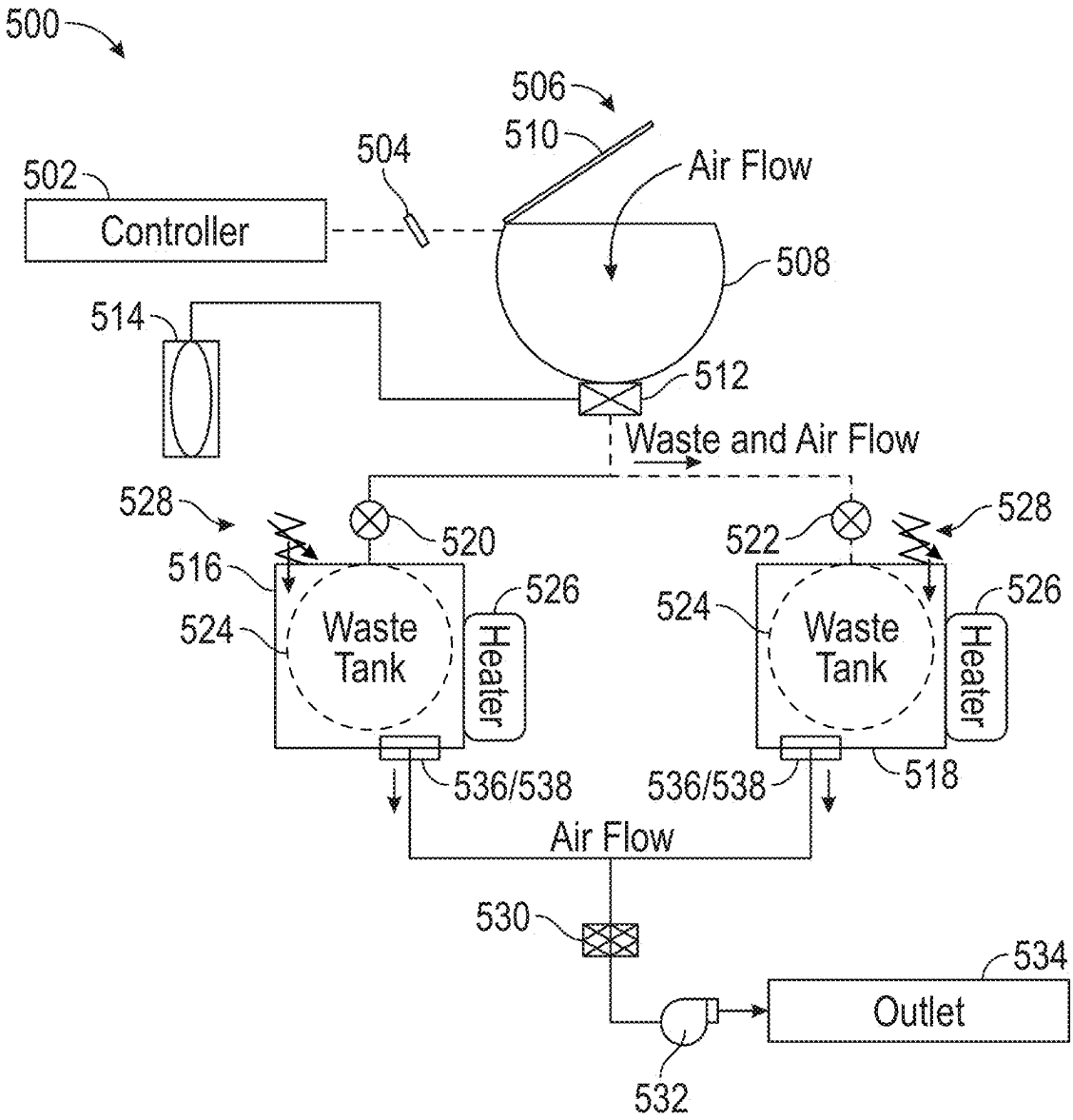

500
506
510
504
Air Flow
502
Controller
508
514
512
Waste and Air Flow
528
520
522
528
516
526
524
Waste Tank
Heater
524
Waste Tank
Heater
526
536/538
536/538
518
Air Flow
530
534
Outlet
532

FIG. 5

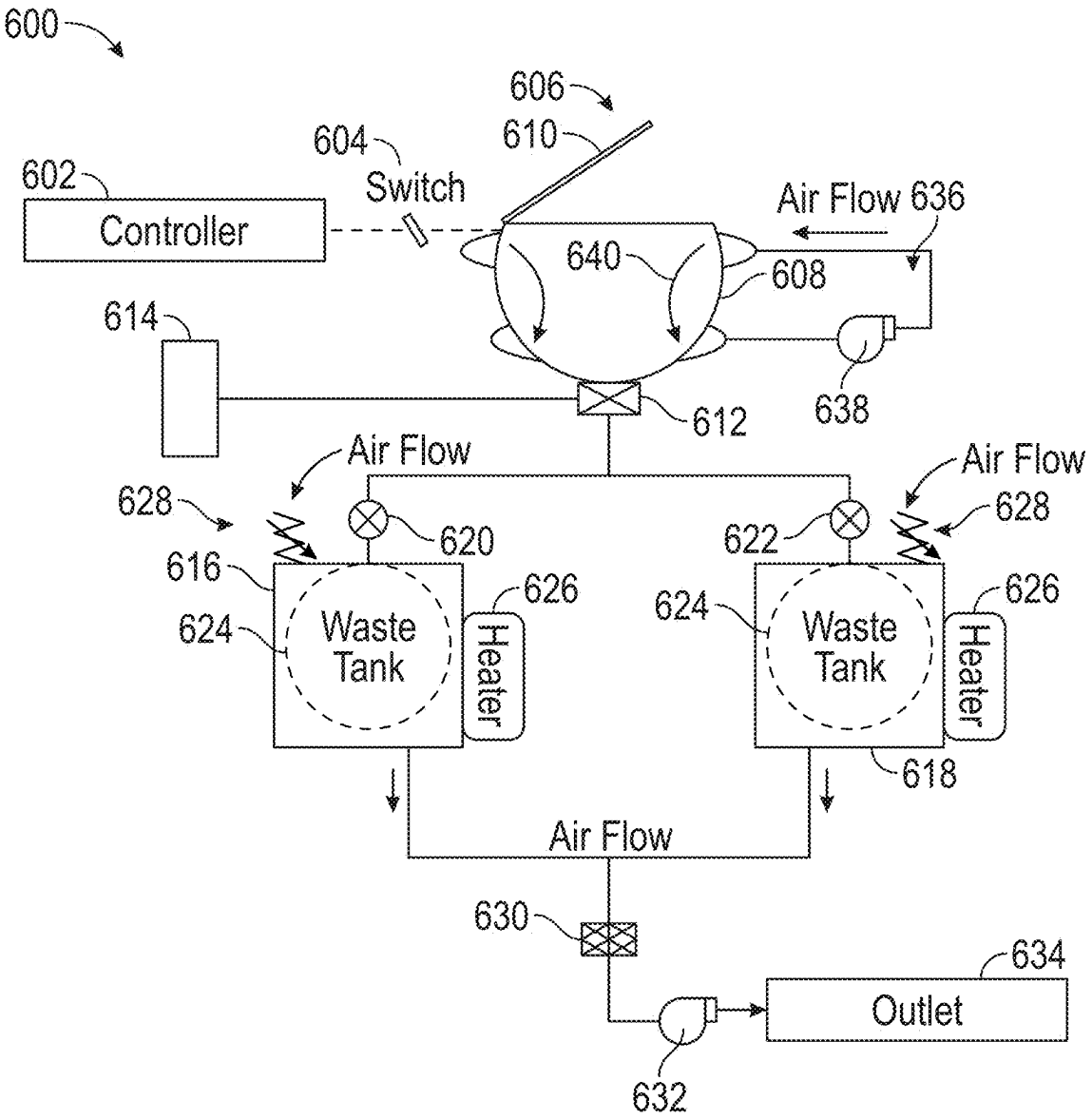

600
606
610
604
Switch
602
Controller
Air Flow 636
640
608
614
638
612
Air Flow
Air Flow
628
620
622
628
616
626
624
Waste Tank
Heater
624
Waste Tank
Heater
626
618
Air Flow
630
634
Outlet
632

FIG. 6

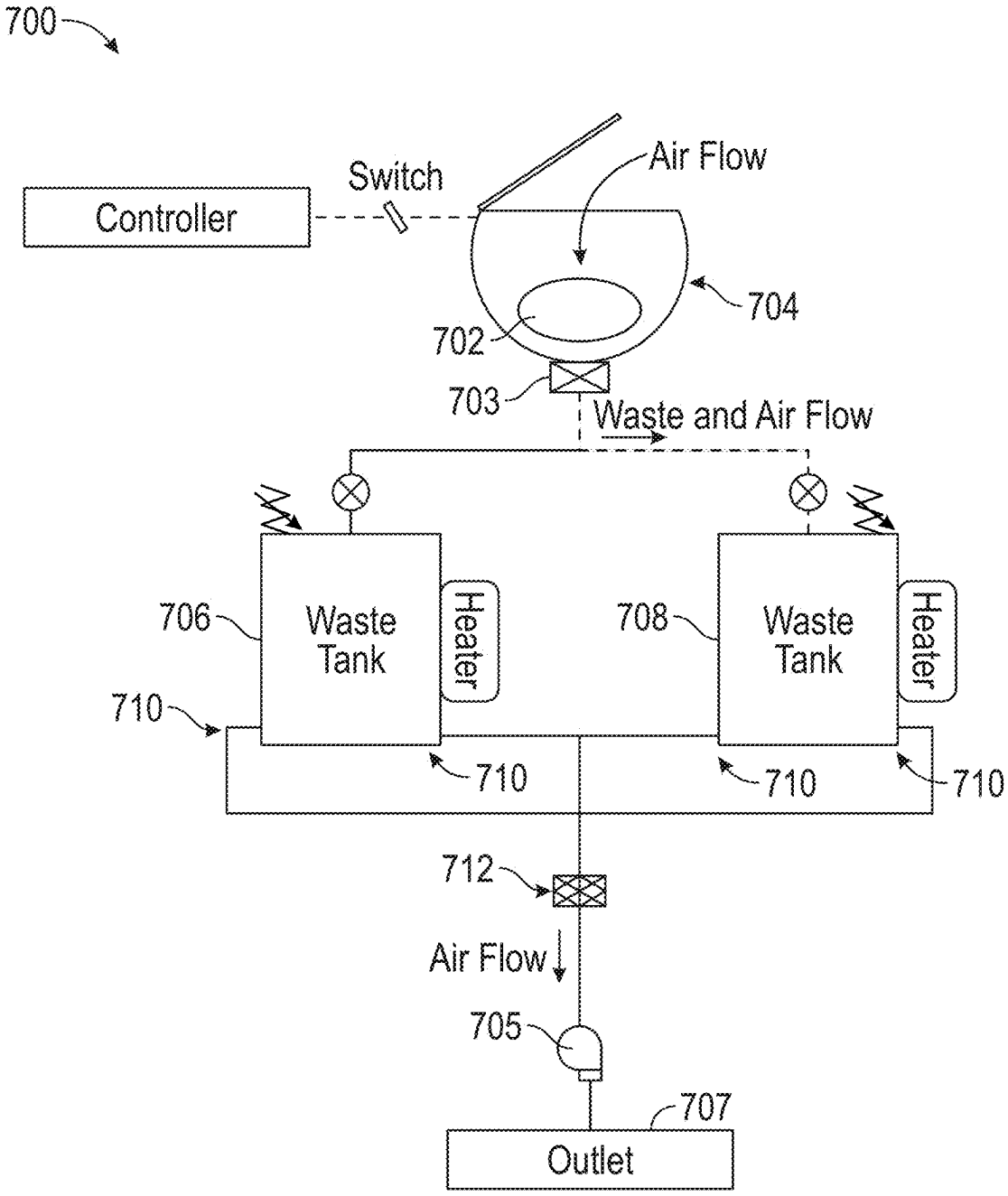

700
Controller
Switch
Air Flow
704
702
703
Waste and Air Flow
706
Waste Tank
Heater
708
Waste Tank
Heater
710
710
710
710
712
Air Flow
705
707
Outlet

FIG. 7

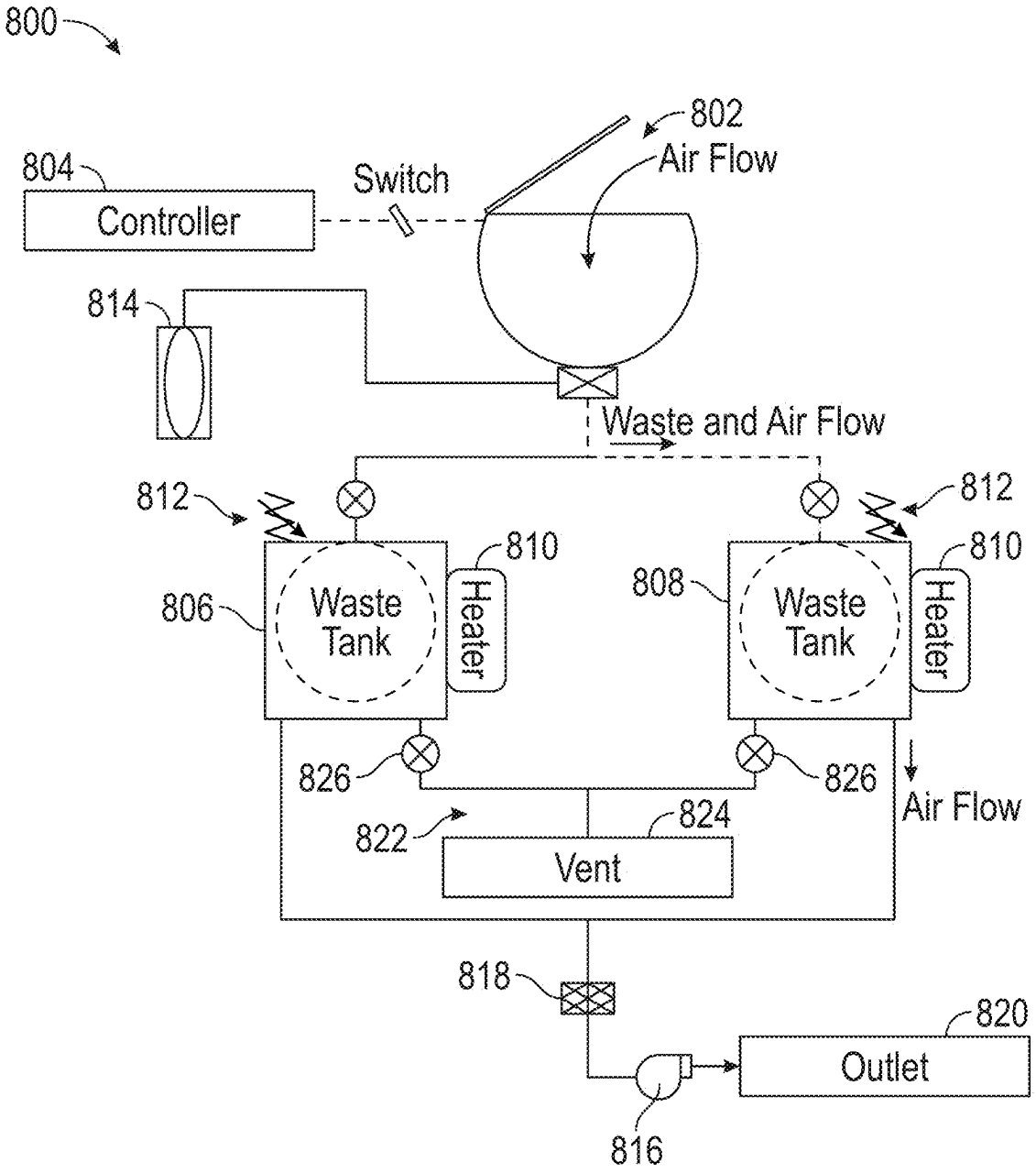

800
802
Air Flow
804
Controller
Switch
814
Waste and Air Flow
812
812
810
810
806
Waste Tank
Heater
808
Waste Tank
Heater
826
826
Air Flow
822
824
Vent
818
820
Outlet
816

FIG. 8

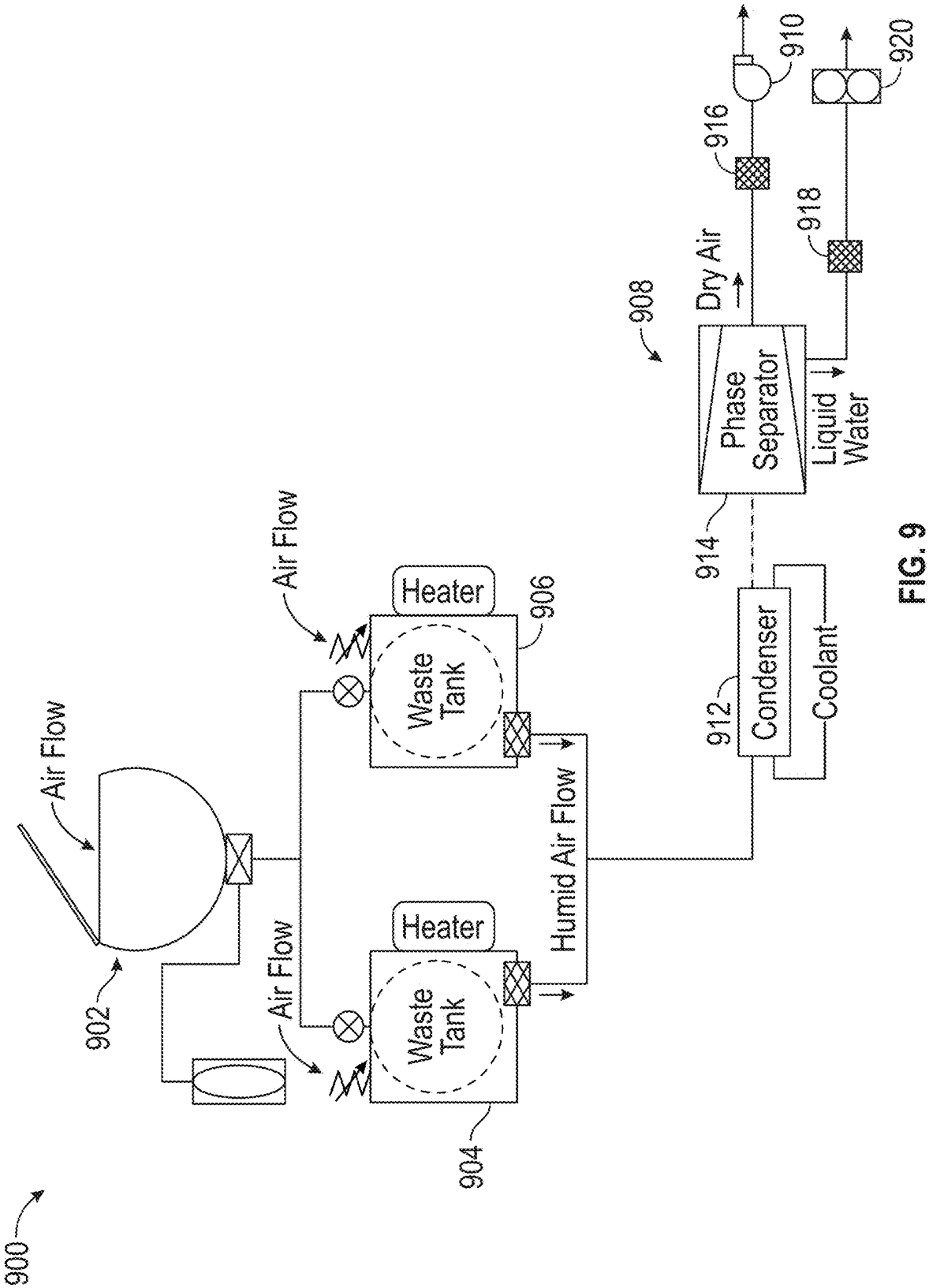

900
902
Air Flow
Air Flow
Air Flow
Heater
Heater
Waste Tank
Waste Tank
904
906
Humid Air Flow
908
912
Condenser
Coolant
914
Phase Separator
Dry Air
Liquid Water
916
918
910
920

FIG. 9

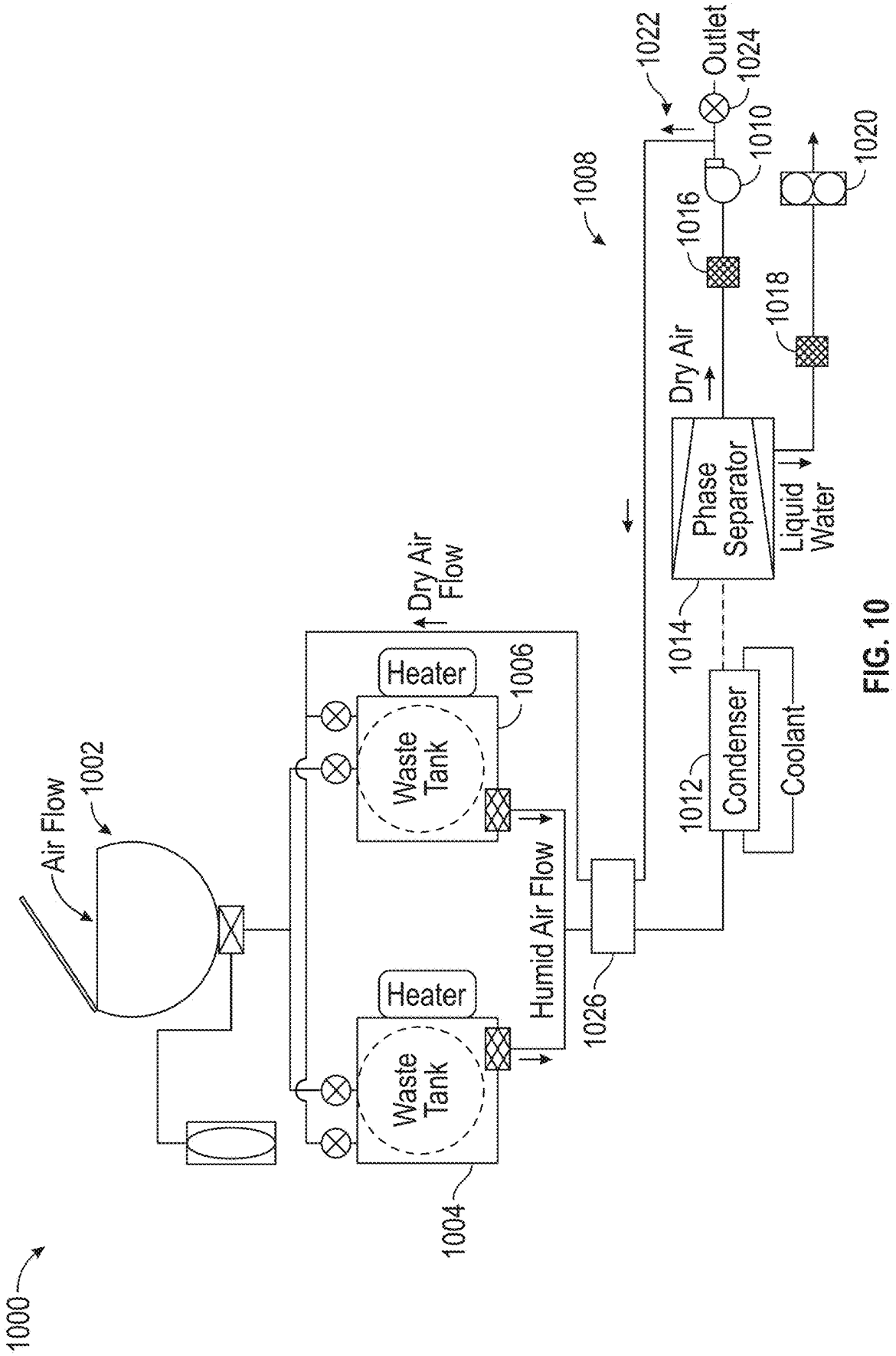

1000
Air Flow
1002
Heater
Waste Tank
1004
1006
Dry Air Flow
Humid Air Flow
1026
1008
1022
Outlet
1024
1010
1016
1018
1020
Dry Air
Phase Separator
Liquid Water
1014
1012
Condenser
Coolant

FIG. 10

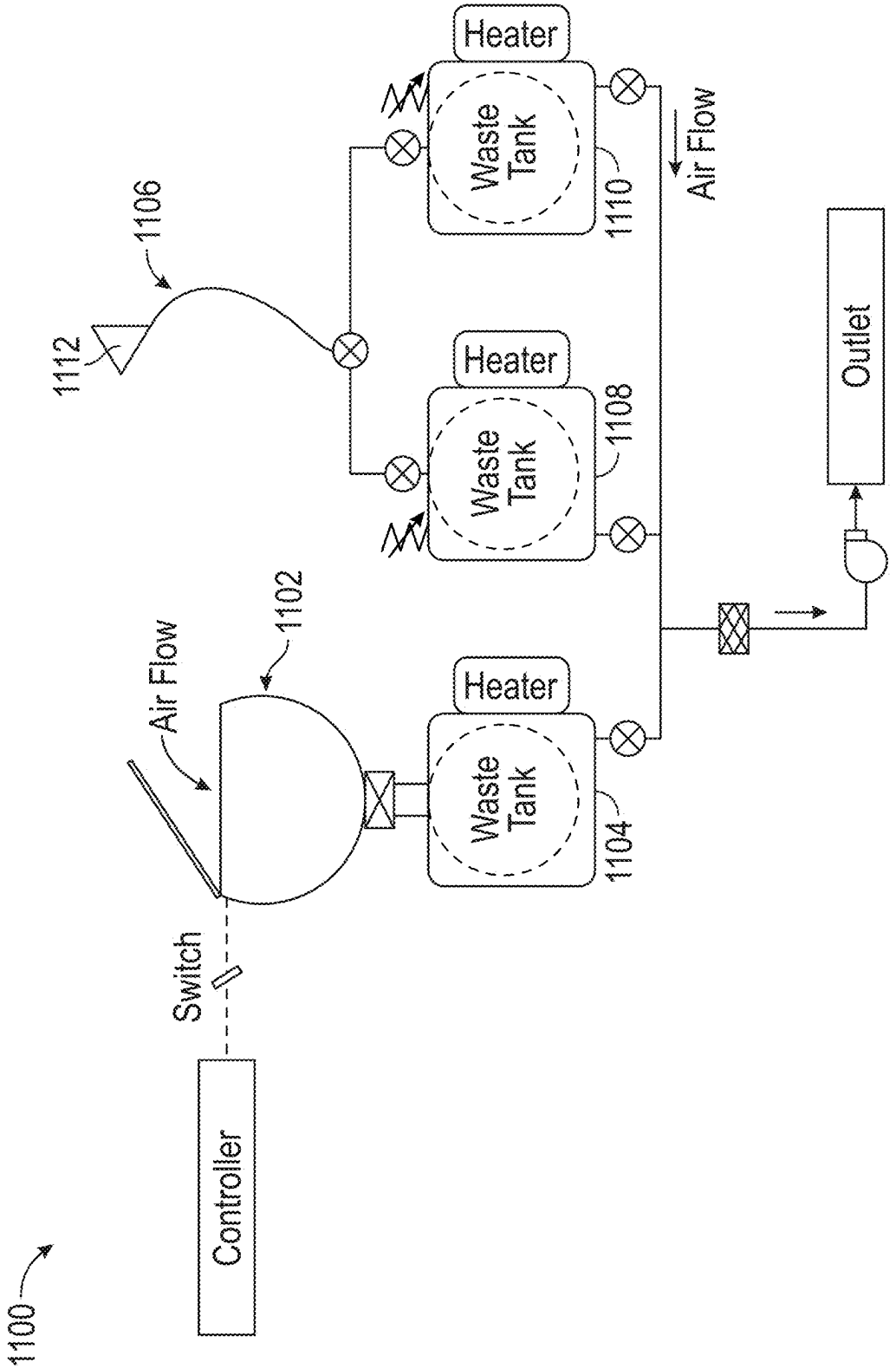

1100
Controller
Switch
Air Flow
1102
Heater
Waste Tank
1104
Heater
Waste Tank
1108
Heater
Waste Tank
1110
Air Flow
1106
1112
Outlet

FIG. 11

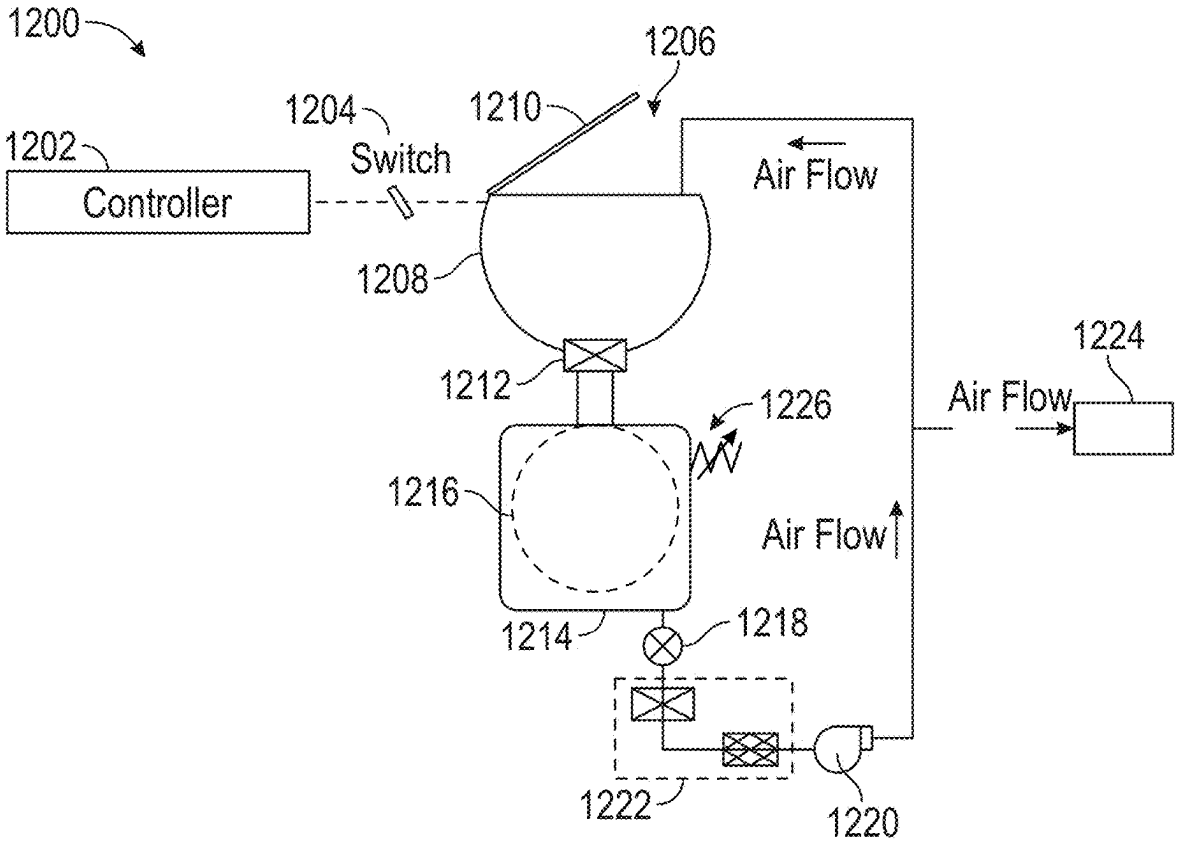

1200
1206
1204
1210
1202
Switch
Controller
Air Flow
1208
1224
1212
1226
Air Flow
1216
Air Flow
1214
1218
1222
1220

FIG. 12

SYSTEMS FOR HUMAN WASTE COLLECTION AND PROCESSING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/552,255 filed Feb. 12, 2024, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] The subject matter disclosed herein generally relates to systems for collection and processing of human waste and, more particularly, to various systems and collection devices for processing human waste in low-gravity and/or space environments.

[0003] When humans reside in relatively closed spaces or environments (e.g., on ships, aircraft, spacecraft, stations, habitats, etc.), or in remote locations or the like, human waste must be managed to avoid contamination or disease and to ensure sanitary conditions for human safety. If conventional plumbing is not required or possible, or there are environmental impacts to plumbing functionality, specific or uniquely designed systems may be required to manage human waste. For example, when in low, micro, or no gravity environments (e.g., in space or on non-Earth celestial bodies), a lack of gravity or reduced gravity may prevent conventional plumbing from being employed, as such systems may rely upon gravity for operation thereof. Further, due to a lack of gravitational force, containment of liquids and solids is an important consideration, particularly for containment of waste that can pose health or other hazards or risks. Additionally, due to the limitations of closed-system environments, particularly in spacecraft, processing of waste and reclamation of water may be important for reducing the total consumable load of the platform.

[0004] In current space-based applications, four systems (i.e., a toilet, a urine processor assembly, a brine processor assembly, and a fecal processor assembly) are required to most thoroughly collect, store, and process human waste. For use of these systems, the toilet requires separate collection of urine (liquid) and non-urine waste (liquid, solid, etc.). Requiring separate collection of urine and non-urine waste streams results in complex requirements and design constraints on the space toilet solution including separate urine and non-urine waste collection ports, which may not be intuitive or as user-friendly as terrestrial designs, particularly for women. Separate urine and non-urine waste collection ports minimizes the ability to reuse hardware and system configurations from terrestrial applications, such as components used for aircraft lavatories or the like. Accordingly, improved systems for waste capture and processing may be advantageous in a variety of applications, including systems that are used in low-gravity environments (e.g., in space).

SUMMARY

[0005] Embodiments of the present disclosure are directed to waste collection and processing systems and related methods of use. The systems described herein may be implemented and installed and used for space-based applications, such as in low-gravity environments, zero-gravity environments, low-gravity surface environments, and the like. Embodiments of the present disclosure provide for improved systems that may reduce weight and complexity while improving system efficiency related to recapture of air and/or water from human waste.

[0006] The foregoing features and elements may be combined in various combinations without exclusivity, unless expressly indicated otherwise. These features and elements as well as the operation thereof will become more apparent in light of the following description and the accompanying drawings. It should be understood, however, that the following description and drawings are intended to be illustrative and explanatory in nature and non-limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The subject matter is particularly pointed out and distinctly claimed at the conclusion of the specification. The foregoing and other features, and advantages of the present disclosure are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0008] FIG. **1** is a schematic illustration of a first illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0009] FIG. **2** is a schematic illustration of a second illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0010] FIG. **3** is a schematic illustration of a third illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0011] FIG. **4** is a schematic illustration of a fourth illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0012] FIG. **5** is a schematic illustration of a fifth illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0013] FIG. **6** is a schematic illustration of a sixth illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0014] FIG. **7** is a schematic illustration of a seventh illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0015] FIG. **8** is a schematic illustration of an eighth illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0016] FIG. **9** is a schematic illustration of a ninth illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0017] FIG. **10** is a schematic illustration of a tenth illustrative configuration of a waste collection and processing system in accordance with the present disclosure;

[0018] FIG. **11** is a schematic illustration of an eleventh illustrative configuration of a waste collection and processing system in accordance with the present disclosure; and

[0019] FIG. **12** is a schematic illustration of a twelfth illustrative configuration of a waste collection and processing system in accordance with the present disclosure.

DETAILED DESCRIPTION

[0020] When humans reside in relatively closed spaces or environments (e.g., on ships, aircraft, spacecraft, bases, habitats, etc.), or in remote locations or the like, human waste must be managed to avoid contamination and/or disease and to ensure proper sanitation. If conventional

plumbing is not required or possible or there are environmental impacts to plumbing functionality, specific or uniquely designed systems may be required to manage human waste. For example, when in low, micro, or no gravity (e.g., in space), a lack of gravity prevents conventional plumbing from being employed. Further, due to the lack of gravity, containment of liquids and solids is an important consideration. Additionally, due to the limited closed-system environments, particularly in spacecraft, processing of waste and reclamation of water may be important for reducing the total consumable load of the platform. As used herein, the terms "low-gravity" and "low-gravity environment(s)" refer to non-Earth based environments that have a gravity less than the gravity of Earth (e.g., less than 1 g). These terms are thus intended to be inclusive of low-gravity (e.g., asteroids, moons, Mars, etc.) and zero-gravity (e.g., onboard spacecraft traveling between celestial bodies, craft and stations in orbit, etc.), and similar environments and is inclusive of artificial gravity applications.

[0021] In current space-based or low-gravity applications, waste collection and processing is typically achieved using four systems (e.g., a toilet, a urine processor assembly, a brine processor assembly, and a fecal processor assembly). These four systems may be required to provide a thorough and complete collection, storage, and processing of human waste. For use of these systems, the toilet requires separate collection of urine and non-urine waste. Requiring separate collection of urine and non-urine waste streams results in complex requirements and design constraints on the space toilet solution. For example, separate urine and non-urine waste collection ports may be required, which may not be intuitive or user-friendly as conventional terrestrial designs, particularly for women. Additionally, the use of separate urine and non-urine waste collection ports minimizes the ability to reuse hardware from terrestrial (or Earth-based) applications, such as components used for aircraft applications or the like. Such systems may also require the inclusion of a pre-treat mechanism, which is a waste treatment fluid that controls microbial growth and prevents solids from forming or ammonia off-gassing during processing. Accordingly, improved systems for waste capture and processing may be advantageous in a variety of applications.

[0022] In current waste collection systems used in low-gravity environments, (e.g., onboard spacecraft), the waste collection systems enable collection of human waste and reclamation of water present in the waste. The necessary functions of waste collection and storage, along with reclamation of water from such waste, can drive the design of such systems to be complex and special-purpose, requiring unique or special-made components. The low-gravity environments that may require unique waste collection systems, beyond spacecraft applications, includes, without limitation, space stations (e.g., orbit), deep space exploration (e.g., space travel), and non-Earth surface operations (e.g., on the surface of the Moon, Mars, asteroids, and other relatively low-gravity bodies). Some such applications may not require toilets that are compatible with a zero or no-gravity environments, but may require systems that are lighter, smaller, more reliable and provide longer life, and require fewer consumables than conventional (e.g., Earth-based) toilet and processing solutions. That is, for some space surface applications, the complexity and features necessary for zero-gravity applications are not as strict, and thus such space surface application toilets may allow for less complexity than zero-gravity applications.

[0023] In view of the above and other considerations, some embodiments of the present disclosure are directed to space and/or space surface applications that incorporate a vacuum for providing motive force within a waste collection system, such as a human waste collection and processing system. In accordance with such embodiments, a commode or toilet with waste storage features that leverages a vacuum system is adapted for use in space. Such systems are capable of use in environments imposed by Deep Space applications (e.g., reduced gravity, increased radiation, etc.). In some embodiments, radiation tolerant electronics and/or redundant and maintainable radiation tolerance strategies may be implemented. Furthermore, such waste collection and processing systems may be used for non-surface operations, such as onboard spacecraft or stations that provide artificial gravity.

[0024] In accordance with some of the space surface applications described herein, some hardware from aircraft applications may be employed. However, because such systems are intended for use under the gravity of Earth, application to low-gravity environments may require modifications or complete rework of certain features and/or systems to enable functional operation in low-gravity environments. For example, application to low-gravity environments may require a need for reclamation from waste (e.g., water and/or air) and/or water/air loss minimization. As such, modifications of conventional aircraft systems is required for consideration of application to low-gravity environments. In accordance with some embodiments of the present disclosure, a single source (e.g., all types of human waste) or separate source waste collection (e.g., urine versus non-urine human waste), with options for rinse and/or waste treatment mechanisms are provided. In some embodiments, an optional vacuum generation or motive force may be achieved by exposure to the vacuum of space (or low atmospheric pressure environment) or use of a vacuum pump may be employed to generate a motive force on the waste to drive the waste through the system without the aid of gravity. In accordance with some embodiments, the total complexity and cost of the system may be reduced by relying upon manual maintenance and cleaning (e.g., at a given interval) as compared to powered cleaning and/or maintenance systems. In other embodiments, an automated or automatic rinse mechanism or other cleaning mechanism may be implemented. In still other embodiments, disposable bowls, cups, collectors, or other consumables (e.g., liners or the like) may be used, thereby reducing or eliminating the need for direct cleaning of a bowl or other structure used to receive human waste.

[0025] Referring now to FIG. **1**, a schematic diagram of a waste collection and processing system **100** in accordance with an embodiment of the present disclosure is shown. The waste collection and processing system **100** may be configured to collect and process human waste (e.g., urine, feces, menses), and is configured to be implemented, used, and operated in low-gravity environments. The waste collection and processing system **100** includes a toilet **102** having a bowl **104** and a lid **106**. In use, a user will open the lid **106** and deposit waste into the bowl **104** where the waste will be collected and processed within the waste collection and processing system **100**, as described herein. In some embodiments, the lid **106** may be configured to sealingly

engage with a surface or rim of the bowl **104**. The waste that is deposited into the toilet **102** may have liquid and solid components, and reclamation of water from the waste may be desirable for users of systems in low-gravity environments (e.g., space stations, spacecraft, non-Earth stations, etc.). Accordingly, the waste collection and processing system **100** is configured to extract the water content from the waste deposited into the toilet **102**.

[0026] As shown, the toilet **102** is configured with a first valve **108** that is operated to allow for waste within the bowl **104** of the toilet **102** to be pulled into a waste tank **110**. In a closed state, the first valve **108** prevents fluid communication from the bowl **104** to the waste tank **110**. The first valve **108** may be selectively opened to provide fluid coupling or connection between an interior of the bowl **104** and an interior of the waste tank **110**. In some embodiments, the first valve **108** may be operably controlled by a controller **112** of the waste collection and processing system **100**. In other embodiments, the first valve **108** may be manually controlled with a lever, foot pedal, or the like. The controller **112** may include various processors, memory, input/output components, and the like, as will be appreciated by those of skill in the art. In other configurations, the controller **112** may be a more basic controller, receiving input and output and causing opening and/or closing of valves, without programmed control (e.g., operable like a switch for on/off or open/closed). The waste collection and processing system **100** may include a switch **114** to cause operation of the waste collection and processing system **100**. For example, activation or operation of the switch **114** may cause the first valve **108** to open and/or close. In some configurations, the switch **114** may be a manually operated switch that is toggled by a user after depositing waste into the toilet **102**. In other embodiments, the switch **114** may integrated into the bowl **104** and/or lid **106** such that when the lid **106** is closed on the bowl **104**, the switch **114** is actuated or operated to cause the first valve **108** to open and transfer any deposited waste within the bowl **104** into the waste tank **110**.

[0027] As shown, one or more optional fluid injectors **116**, **118** may be provided to inject water, cleaning fluid, waste treatment fluid, or the like, directly into the bowl **104** and/or to be mixed with the waste as it is transferred from the bowl **104** to the waste tank **110** (e.g., within the first valve **108** or upstream or downstream therefrom). The fluid injectors **116**, **118** can provide for an optional first processing step that is initialized at the time a user completes their deposit of waste into the toilet **102**. The injected fluids or chemicals provided by the fluid injectors **116**, **118** may initiate a waste treatment and processing and/or may provide for cleaning of surfaces of the lid **106**, the bowl **104**, the first valve **108**, and/or the piping and conduits connecting the bowl **104** to the waste tank **110**.

[0028] The waste is then collected within the waste tank **110**. The waste tank **110** may be an enclosure for receiving human waste. The waste tank **110** may, in some embodiments, include bags, filters, disposable components, or the like, for the purpose of waste capture and treatment, with considerations made for ensuring liquids and/or solids do not escape the tank **110** and enter a space, room, or area that is occupied by humans (e.g., cabin or the like of a spacecraft). The first valve **108** is arranged at an inlet of the waste tank **110** and, in this configuration, the waste tank **110** may have two outlets each with a respective valve. For example, as shown, a second valve **120** may be controlled to selectively open to allow for waste within the waste tank **110** to be directed to a waste outlet **122**, which may include an optional pump for providing a motive force to move the waste from the waste tank **110** to the waste outlet **122**. The waste outlet **122** may be configured to receive solid waste, liquid waste, or a combination of solid and liquid waste, depending on the specific application and configuration of the system. The waste outlet **112** may define a flow path for waste to travel to storage or additional processing locations, such as plumbing.

[0029] At the second outlet of the waste tank **110**, a third valve **124** is provided. The third valve **124** may be configured to allow for gas extraction from the waste tank **110**. As such, the third valve **124** may be configured to permit, at most, liquids and gases, but may be configured to prevent solid waste to pass therethrough. The third valve **124** may be configured as part of an air and/or water reclamation system that directs airflow from the waste tank **110** through various systems, and may be configured to recycle treated gas (e.g., air) back into an occupied space **126** (e.g., spacecraft cabin) or direct treated or untreated gases to an external environment **128** (e.g., space, low-pressure atmosphere, etc.). In some embodiments, and as shown, an optional de-mister **130** may be provided at an outlet of the waste tank **110** and upstream from the third valve **124** (i.e., between the waste tank **110** and the third valve **124**). In other embodiments, the de-mister may be arranged downstream from the third valve **124**. The optional de-mister **130** may be a passive or active device for causing moisture from an airflow passing from the waste tank **110** to be removed. In some configurations, the de-mister **130** may be configured as a tortuous flow path with baffles or the like that are impinged upon by the airflow, causing moisture to condense out of the air. As such, the de-mister **130** may be included to generate a relatively dry air that is output from the waste tank **110**. In configurations where the extracted air is to be supplied back into the occupied space **126**, the airflow may be passed through an air filter assembly **132**. The air filter assembly **132** can include odor and/or bacterial filters and the like to remove any odors or bacteria that may still be carried on the flow of air from the waste tank **110**. Such treated air may be supplied into the occupied space **126**, such as a spacecraft cabin or the like.

[0030] In some configurations, a pump **134**, such as a vacuum pump, may be configured to induce a motive force to drive the air from the waste tank **100**, through the de-mister **130**, the third valve **124**, and the air filter assembly **132** to generate treated air that can be directed into the occupied space **126**. In some configurations, the pump **134** may be controllable or selectively operated by the controller **112** or another controller associated with the waste collection and processing system **100**. In embodiments where the air from the waste tank **110** is to be directed to the exit at the external environment **128**, the external environment **128** itself may provide the vacuum or motive force for pulling the airflow from the waste tank **110**. It will be appreciated that although both fluid paths are illustrated (e.g., to the occupied space **126** and the external environment **128**), in other embodiments, only one of these two fluid paths may be present. Further, in some embodiments, a valve or the like may be arranged at the junction/split to the two exits, which may be manually or automatically controlled (e.g., by controller **112**).

[0031] The airflow paths downstream from the third valve **124** may include additional components and the like, as will be appreciated by those of skill in the art. For example, and without limitation, in some embodiments, the flow paths to either exit may include various dehumidification hardware such as desiccant bed(s), condensing heat exchanger(s), additional passive or active de-mister systems, and the like. Further, at the waste outlet **122**, additional processing may be employed to further process the waste after the waste is removed from the waste tank **110**, such as water reclamation or the like.

[0032] In accordance with some embodiments of the present disclosure, the waste collection and processing system **100** may be configured for operation in three modes. A first mode of operation may be referred to as a system reset operation, a second mode of operation may be referred to as a waste deposit operation, and a third mode of operation may be referred to as a waste removal operation. The various operational modes may be controlled, at least in part, by the controller **112**.

[0033] In the first operational mode (System Reset Operation), the controller **112** will cause both the first valve **108** and the second valve **120** to enter a closed state (if not already in a closed state). The controller **112** will then cause the third valve **124** to open. If the system **100** is configured to vent to vacuum or low pressure atmosphere (e.g., external environment **128**), air in the waste tank **110** is vented to the external atmosphere, and the waste tank **110** is brough to a low pressure state (e.g., lower than ambient pressure within the occupied space **126**, inclusive of vacuum pressure). If the system **100** is configured to return air back to a cabin or the like (e.g., occupied space **126**), the controller **112** may be configured to activate the pump **134**, which will cause air within the waste tank **110** to be extracted therefrom and the waste tank **110** may be brought to a low pressure state. As noted above, the configuration illustrated in FIG. **1** is merely schematic and a system in accordance with the present disclosure may include only one of the two airflow paths that exit from the waste tank **110** and/or the third valve **124** may be configured to selectively direct an airflow into one of the two distinct flow paths (e.g., to the external environment **128** or to the occupied space **126**). With the waste tank **110** brought to a low pressure state, the third valve **124** will then be closed (resulting in all three valves **108**, **120**, **124** being closed). At this point, the waste collection and processing system **100** is ready to be used.

[0034] In the second operational mode (Waste Deposit Operation), airflow, gravity, or combinations thereof may be employed to direct human waste deposited by the user into the toilet **102** to be directed into the waste tank **110**. In such an operational mode, opening of the lid **106** may optionally actuate a mechanical switch (e.g., the switch **114**) which can activate the controller **112**. In other embodiments, a user may toggle or actuate the switch **114** to initiate the waste deposit operation. Due to the fact that the systems of the present disclosure may be implemented onboard spacecraft, and such spacecraft may be exposed to radiation, consideration of the effects of such radiation on the system may be important. For example, radiation effects scale with duty cycle, and the inclusion of a switch **114** that is tied to opening/closing of the lid **106** may minimize the duration in which the controller **112**, and potentially any other associated electronics, is powered on, resulting in minimizing the impact of radiation exposure to the electronic components.

[0035] In the second mode of operation, a user will deposit human waste into the bowl **104**, similar to toilet use in terrestrial applications. When the user has completed use of the toilet **102**, a 'flush' is activated by operation of the switch **114**, such as by manual actuation of the switch **114** by the user after closing the lid **106** or by the actuation of the switch **114** by closing the lid **106**. When the 'flush' is activated, the controller **112** directs the first valve **108** to open. During use (e.g., depositing waste), the toilet **102** will be exposed to the surrounding ambient atmosphere (e.g., ambient pressure of the occupied space **126**), and thus the bowl will have a pressure that is about at atmospheric pressure. When the first valve **108** is opened, the volume of the toilet **102** will be exposed to the low pressure state within the waste tank **110** that is generated during the first operational mode. It is noted that the opening of the first valve **108** may be tied to the lid **106** in some manner to ensure that the first valve **108** does not open when the lid **106** is open. With the lid **106** closed and the first valve **108** opened, the pressure differential between the toilet **102** and the waste tank **110** will create a suction force and cause the waste within the bowl **104** to flow into the waste tank **110**.

[0036] Before, during, or after the second mode of operation, an optional cleaning or treatment step may be performed. For example, before or during the opening of the first valve **108**, a first fluid injector **116** may be operated to direct water, cleaning fluid, or waste treatment fluids into the bowl **104**, and/or a second fluid injector **118** may be operated to direct similar fluids into the first valve **108** or within or along a flow pipe/path that connects the bowl **104** to the waste tank **110**. The fluids injected by the fluid injectors **116**, **118** may be pulled into the waste tank **110** along with the waste. Once the waste (and optional treatment and/or cleaning fluids) has been pulled into the waste tank **110**, the first valve **108** may be closed, fluidly sealing the connection between the toilet **102** and the waste tank **110**. The controller **112** may then perform the first operational mode (System Reset Operation), as described above, resetting the system **100** for another user. This sequence of the first and second operational modes may be performed until the waste tank **110** reaches capacity or when the third operational mode is initiated.

[0037] In the third operational mode (Waste removal), waste is removed from the waste collection and processing system **100** by opening the second valve **120** and either pumping waste out (pump not shown) or using gravity to remove waste from the waste tank **110**. As discussed above, the resetting operation will cause removal of gases from the waste tank **110**. However, the solid and liquid waste deposited within he waste tank **110** will be held in the waste tank **110**. During the waste removal operation, the waste is removed from the waste tank **110** and directed to the waste outlet **122**. In some configurations, and during the waste removal operation, a rinsing operation may be performed within the waste tank **110** to clean or remove any waste that may be attached to the sides of the waste tank **110** and/or such fluid may aid in removing the waste from the waste tank **110**. During the waste removal operation, the waste may be directed into a waste processing system or the like, where water extraction and/or reclamation and/or other waste processing may be performed. In some embodiments, the waste tank **110** may be configured with rinsing capabilities that are initiated and operated at the completion of the third operational mode. Such rinsing operations may

include one or more additional fluid injectors arranged to inject fluids (e.g., water, cleaning fluids, disinfectants, etc.) into the waste tank **110**.

[0038] It will be appreciated that various sensors, detectors, monitors, and the like may be arranged throughout the waste collection and processing system **100**. For example, various configurations may include sensors for lid state (e.g., open/closed), air flow rates, air pressure, liquid and/or solid levels within the toilet **102** and/or waste tank **110**, weight, or other sensors to detect fill level within the waste tank, valve state sensors (e.g., open/closed), temperature sensors, moisture sensors, and the like. Each of the sensors may be in arranged operable communication with the controller **112** to provide feedback and/or to enable automation of various aspects described herein. It will be appreciated that such sensors may be implemented with any of the herein described embodiments and such sensors are not merely limited to the embodiment and configuration shown and described with respect to FIG. **1**.

[0039] Referring now to FIG. **2**, a schematic diagram of a waste collection and processing system **200** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **200** may be similar to the configuration shown in FIG. **1**, but with differences as shown and described herein. The waste collection and processing system **200** may be used aboard spacecraft or on a base or other structure on the surface of a non-Earth body (i.e., in low-gravity environments). Similar to the configuration shown in FIG. **1**, the waste collection and processing system **200** includes a toilet **202** with a bowl **204** and a lid **206**. Waste from the toilet **202** may be selectively directed from the bowl **204** into a first waste tank **210** (e.g., a solid waste tank) through a first valve **208** that is controlled by a controller **212**. A switch **214** may be employed for control functionality, as described above. Similarly, one or more optional fluid injectors **216**, **218** may be provided to inject water, cleaning fluid, waste treatment fluid, or the like, directly into the bowl **204** and/or to be mixed with the waste as it is transferred from the bowl **204** to the first waste tank **210**.

[0040] Waste may be collected from the first waste tank **210** through a second valve **220** that selectively controls fluid connection between the first waste tank **210** and a first waste outlet **222**, similar to that described above. In some configurations, the first waste tank **210** may be fluidly connected to an occupied space **226** (e.g., spacecraft cabin) via a flow path having a third valve **224** arranged thereon. In other embodiments, the first waste tank **210**, in combination with the third valve **224**, may be configured to direct treated or untreated gases to an external environment **228** (e.g., space, low-pressure atmosphere, etc.). In still further configurations, such as shown in FIG. **2**, the system **200** may be configured to allow selective fluid to either or both of the occupied space **226** and the external environment **228**. An optional de-mister **230** may be provided along the flow path exiting the first waste tank **210**, as described above. In configurations or operations where air is to be directed back into the occupied space **226**, the air may pass through a filter assembly **232** and a motive force may be provided by a pump **234**, such as a vacuum pump.

[0041] The waste collection and processing system **100** of FIG. **1** is a combined collection system. However, in contrast, the waste collection and processing system **200** of FIG. **2** provides for two separate collection mechanisms or systems. The toilet **202** of the waste collection and processing system **200** of FIG. **2** may be configured to receive solid waste, or non-urine waste, although such solid waste deposit may include urine as well. However, if a user intends to only deposit liquid waste (e.g., urine), the waste collection and processing system **200** includes a dedicated system for such waste. As shown, the waste collection and processing system **200** includes a liquid waste collection system **236** which is arranged as a parallel system with the solid waste collection provided by the toilet **202**.

[0042] The liquid waste collection system **236**, as shown, includes a liquid waste receptacle **238** or other receiving device which is fluidly connected to a second waste tank **240** (e.g., a liquid waste tank). A fourth valve **242** is arranged between the liquid waste receptacle **238** and the second waste tank **240** (e.g., along a hose, conduit, or the like). The second waste tank **240** may be configured similar to that of the first waste tank **210**, but may be configured to receive only liquid waste. As shown, the fourth valve **242** is arranged at an inlet to the second waste tank **240**, and a fifth valve **244** is arranged between the second waste tank **240** and a second waste outlet **246**. Further, as shown, a sixth valve **248** may be provided at an outlet from the second waste tank **240** to enable extraction of gases from the second waste tank **240**, and may include an optional de-mister **250** at the outlet thereof, similar to the configuration of the first waste tank **210**.

[0043] Similar to the configuration of FIG. **1**, the waste collection and processing system **200** has three operating modes.

[0044] In a first operational mode (e.g., System Reset Operation), the controller **212** will control the first valve **208**, the second valve **220**, the fourth valve **242**, and fifth valve **244** to be closed. The controller **212** will then control the third valve **230** and the sixth valve **248** to open (either separately or simultaneously). By opening only the third valve and/or the sixth valve **248**, the respective waste tanks **210**, **240** may be vented and reduced in pressure for subsequent use of the system **200**. In configurations or operations where the waste collection and processing system **200** is configured to vent to vacuum or a low pressure atmosphere (e.g., external environment **229**), air in the waste tanks **210**, **240** is vented to external atmosphere and the waste tanks **210**, **240** are brought to low pressure (or vacuum). If the waste collection and processing system **200** is configured to return the air to the occupied space **226**, the controller **212** will activate the pump **234** to draw the air through the filter assembly **232**, and the waste tanks **210**, **240** are brought to low pressure (or vacuum). The controller **212** will then close the third valve **230** and the sixth valve **248**. At this point, in either venting operation, the pressure within the waste tanks **210**, **240** is lower than ambient pressure within the occupied space **226**, and the system **200** is ready for use.

[0045] In a second operational mode (e.g., Waste Deposit Operation), airflow, gravity, or combinations thereof may be used to direct human waste deposited from user into the respective waste tanks **210**, **240**. As noted above, optionally, opening the lid **206** or, in this configuration, taking up the liquid waste receptacle **238**, can actuate the switch **214** to activate the controller **212**. This responsive action thus only activates the controller **212** and the system **200** as a whole, when a user will be depositing waste, thus reducing the duty cycle of the electronic components of the system **200**. A user will make a deposit, similar to toilet use in terrestrial

applications but with separate means of collection for urine (liquid waste receptacle **238**) and non-urine waste (toilet **202**). In the second operational mode, the fourth valve **242** can optionally be partially opened to provide a limited amount of air flow to assist with urine capture at the liquid waste receptacle **238**. When a user has completed their waste deposit, a 'flush' action is activated, such as by a switch, toggle, foot pedal, or closing of the lid **206** or replacing the liquid waste receptacle **238** to a stowed location. When the 'flush' action is activated, the controller **212** will cause the first valve **208** and the fourth valve **242** to open, either individually or simultaneously. In some embodiments, only the valve **208**, **242** that is associated with the location of the waste deposit will be opened. During the waste deposit, the bowl **204** and the liquid waste receptacle **238** will be exposed to atmospheric pressure (e.g., the occupied space **226**). When the 'flush' is activated, the toilet **202** and/or the liquid waste receptacle **238** will be exposed to vacuum or low pressure in the respective waste tanks **210**, **240**. This will create a suction force, moving the waste into the respective waste tanks **210**, **240**. In some configurations, at the respective valves **208**, **242** or within the respective bowl **204** or liquid waste receptacle **238**, optional water, cleaning fluid, or waste treatment can be injected using fluid injectors **216**, **218**, **252**. Once the waste has been moved into the respective waste tanks **210**, **240**, the first and fourth valves **208**, **242** are closed and the controller **212** initiates the first operational mode (e.g., System Reset Operation). In some configurations of the waste collection and processing system **200**, the system can also be operated in a way that collects urine and non-urine deposits at different times, or independently, with a different valve opening and closing procedure, without departing from the scope of the present disclosure.

[0046] In a third operational mode (e.g., Waste removal), waste is removed from the system **200**. The waste removal operation may be controlled by the controller **212**. In a first step, the second valve **220** and/or the fifth valve **244** are opened, and waste within the waste tanks **210**, **240** may be pumped out (pump not shown) or the waste may exit the respective waste tanks **210**, **240** by means of gravity. The waste collected at the respective waste outlets **222**, **246** can be directed to waste reclamation hardware. The waste reclamation hardware may include, but is not limited to, urine processor(s), fecal waste processing bag(s), urine processing bag(s), heaters, evaporators, phase separators (e.g., solid, liquid, gas), or the like. In some embodiments, the waste tanks **210**, **240** may be configured with rinsing capabilities that are initiated and operated at the completion of the third operational mode.

[0047] Referring to FIG. **3**, a schematic diagram of a waste collection and processing system **300** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **300** may be similar to the configurations shown in FIGS. **1-2**, but with differences as shown and described herein. The similar features that are illustrated will not be described in detail again for brevity and clarity of differences, but it will be appreciated that unless otherwise stated, embodiments and aspects of the waste collection and processing system **300** may be substantially similar to or even identical to the above described embodiments.

[0048] The waste collection and processing system **300** is a dual-stream configuration, similar to that shown and described with respect to FIG. **2**, but having only one waste collection component (i.e., a toilet **302**). In this configuration, the toilet **302** includes a bowl **304** and a lid **306** with a urine capture element **308** arranged within the bowl **304**. The urine capture element **308** is arranged to ensure separation of liquid waste (urine) from solid or other human waste which will be collected in the bowl **304**. Once the urine is deposited into the urine capture element **308** and other waste is deposited into the bowl **304**, the operational modes described with respect to FIG. **2** are substantially the same, and thus description thereof will not be repeated. That is, the solid and/or non-urine waste may be collected into and processed from a first waste tank **310** (e.g., solid waste tank) and the urine waste may be collected into and processed from a second waste tank **312** (e.g., liquid waste tank).

[0049] Referring to FIG. **4**, a schematic diagram of a waste collection and processing system **400** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **400** may be similar to the configurations shown in FIGS. **1-3**, but with differences as shown and described herein. The similar features that are illustrated will not be described in detail again for brevity and clarity of differences, but it will be appreciated that unless otherwise stated, embodiments and aspects of the waste collection and processing system **400** may be substantially similar to or even identical to the above described embodiments. The primary features shown and labeled in FIG. **4** are related to a waste reclamation system **402** that is incorporated into the waste collection and processing system **400**. The waste reclamation system **402** may be provided to process waste deposited into the system **400** by a user and enable reclamation of portions of the waste (e.g., breathable air, water, etc.).

[0050] Similar to the above described configurations, the waste collection and processing system **400** includes a waste tank **404** that is selectively fluidly connected to the waste reclamation system **402** by a valve **406**. The waste reclamation system **402** includes a condenser **408** (e.g., a condensing heat exchanger) that is thermally coupled to a coolant loop **410**, or the like. The condenser **408** is arranged to cool a fluid flow received from the waste tank **404** as it flows through the waste reclamation system **402**. The condenser **408** will cool the fluid and condense moisture (e.g., water) from the fluid flow. The cooled flow, which may include both gases and liquid water or other liquids, may then be directed into a settling tank **412**, where the liquid and gas components may separate. The settling tank **412**, in some configurations, may be replaced by or arranged in connection with a phase separator or similar component, as will be appreciated by those of skill in the art. However, use of the settling tank **412** along may provide for a low complexity, passive system for separation of liquid and gases output from the waste tank **404**.

[0051] Dry air may be passed from the settling tank **412** through an air scrubber **414** (or other gas processing system/apparatus) and then the treated air may be directed by a fan **416** into an occupied space **418**, or the like. The liquid portion (e.g., water) may be pulled out of the settling tank **412** by a pump **420** and the liquid is passed through a liquid scrubber **422** (or other liquid processing system/apparatus) and then the treated liquid may be directed through a liquid outlet **424**. The liquid outlet **424** may be connected to a water storage tank or other water-based system onboard a spacecraft or the like. It will be appreciated that the air

scrubber **414** and/or the liquid scrubber **422** may be configured with filters, chemical processing hardware, or the like. When the waste reclamation system **402** is not operated or used, the system **400** provides for fluid connection between the waste tank **404** and a return flow to the occupied space **418** or to an external environment, as described above.

[0052] As shown in FIG. **4**, an optional heater **426** may be operably connected to the waste tank **404** to provide heating thereto. The application of heat to the waste tank **4040** may increase an efficiency of the waste reclamation system **402** by evaporating liquid within the waste tank **404** prior to drawing the gases from the waste tank **404** into the waste reclamation system **402**. Although the waste reclamation system **402** is illustratively shown as receiving an airflow from the waste tank **404**, it will be appreciated that a similar waste reclamation system may be provided at a waste outlet **428** that is output from the waste tank **404**. In other configurations, the output at the waste outlet **428** may be directly connected to the same waste reclamation system **402** as that which receives the air to be treated for water reclamation, as described above. As such, in some embodiments, the waste reclamation system **402** may be configured to process both gaseous output and solid/liquid output from the waste tank **404**.

[0053] In the above described embodiments, a pump or other low pressure or vacuum source may be arranged to generate a low pressure within the waste tanks. This low pressure is used to pull waste from a toilet bowl or other receptacle and cause gas, liquid, and solid waste to be pulled from the receptacle into one or more waste tanks. It will be appreciated that, in some embodiments, such pump may not be necessary, such as by exposing the waste tank(s) to a low pressure atmosphere or vacuum of space.

[0054] In accordance with some embodiments of the present disclosure, waste collection and processing systems may be arranged as single stream collection commodes with waste storage and processing capability. In use, waste may be collected from the user with an assisting airflow to pull the waste into the respective receptacle, and, in some embodiments, may be assisted by bowl geometry or the like. The waste may then be separated using various materials, structure, and/or membrane configurations, where solid and liquid waste are captured and gases are allowed to pass through the material/structure/membrane, within the respective waste tank. In some configurations, the waste tank(s) may be configured with heaters or other mechanisms to evaporate water from the collected waste and enable reclamation of the water from the waste. The heating operation may also prepare solid waste remnants (e.g., after gases and liquids have been extracted) for safe storage or disposal. Some such configurations may include an alternating processing chamber architecture to treat and/or remove gases, liquids, and solids. Such systems may be capable of use in environments imposed by Low Earth Orbit and Deep Space applications (e.g., low or no gravity, increased radiation, etc.). In accordance with some embodiments, simultaneous waste stream collection (e.g., liquids and solids) with intuitive human interface may be provided, such as with modified receptacles, or the like. Accordingly, systems of the present disclosure may reduce required crew interaction relative to conventional systems, thus increasing safety and cleanliness. Furthermore, some embodiments of the present disclosure allow for water recapture from all forms of human waste (e.g., urine, feces, vomit, menses, etc.). In accordance with some embodiments, separate waste collection and/or water recapture may be employed with various configurations shown and described herein. For example, and without limitation, such separate waste collection and/or water recapture may be incorporated as shown in FIGS. **2-3**.

[0055] Referring now to FIG. **5**, a schematic diagram of a waste collection and processing system **500** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **500** includes a controller **502**, a switch **504**, and a toilet **506** having a bowl **508** and a lid **510**, similar to that shown and described above, and thus the details of which will not be repeated again. At the outlet of the bowl **508** is a selectively operable first valve **512** that is configured to be controlled by the controller **502**. As shown, a fluid injector **514** may be provided to inject water, cleaning fluid, waste treatment fluid, or the like, directly into the bowl **508** and/or to be mixed with the waste as it is transferred from the bowl **508** to a waste tank of a pair of waste tanks **516**, **518**. Although two waste tanks **516**, **518** are illustratively shown, it will be appreciated that more than two waste tanks may be employed without departing from the scope of the present disclosure.

[0056] The waste tanks **516**, **518** are configured to be selectively operated between a reclamation operation and a collection or containment operation. In the system **500**, one of the waste tanks **516**, **518** may be operated in a reclamation mode of operation while the other waste tank **516**, **518** is operated in a collection or containment mode of operation. In the illustrative configuration, a first waste tank **516** is shown in the reclamation mode of operation and a second waste tank **518** is shown in the collection mode of operation. As noted, the operational state of the two waste tanks **516**, **518** may be selectively switched, such that the first waste tank **516** may be operated in the collection mode of operation and the second waste tank **518** may be operated in the reclamation mode of operation.

[0057] When the first waste tank **516** is in the reclamation mode, and as shown in FIG. **5**, a second valve **520** arranged between the first valve **512** and the first waste tank **516** is closed, thus preventing fluid communication between the toilet **506** and the first waste tank **516**. When the second waste tank **518** is in the collection mode, and as shown in FIG. **5**, a third valve **522** is open, allowing for waste from the toilet **506** to be directed into the second waste tank **518**. In some embodiments, the second and third valves **520**, **522** may be replaced by a directional three-way valve, and the distinct valve arrangement illustrated herein is intended only for explanatory purposes, and is not intended to be limiting to the valve configurations that may be used with embodiments of the present disclosure. The controller **502** may be configured to control operation of the valves **512**, **520**, **522**. In this configuration, each of the waste tanks **516**, **518** includes a waste bag **524** arranged within the respective waste tank **516**, **518**. The waste bags **524** are configured to capture liquid and solid waste, but is permeable to gases that are part of the waste that is deposited into the waste bags **524**. As such, the gasses of the waste may be extracted, reclaimed, and recycled for use. In some embodiments, the waste bags **524** may be configured as a multi-membrane bladder or the like.

[0058] Each of the waste tanks **516**, **518** may include an optional heater **526** that is arranged to promote extraction of gases, and potentially water, from the waste in the waste bags **524** within the respective waste tanks **516**, **518**. In

various embodiments, the optional heaters **526** may be placed on the outside of the respective waste tanks **516**, **518**, inside the waste tanks **516**, **518**, upstream of the waste tanks **516**, **518** on a fluid line between the toilet **506** and the waste tanks **516**, **518**, and/or on or at air inlets or pressure relief valves **528** that are associated with the waste tanks **516**, **518**. Further, it will be appreciated that multiple separate heaters may be arranged at multiple locations to ensure desired heating of the waste stream or captured waste. In some configurations, and as shown, air from an occupied space (or from a dedicated supply) may be passed or forced through the waste tanks **516**, **518** from the respective air inlets **528**. In some embodiments, the air supplied through the air inlets **528** may be openings that are always open, thus allowing constant flow of air to pass through the waste tanks **516**, **518**. In other configurations, the air inlets **528** may include operation valves (e.g., pressure relieve valves, controllable orifices, etc.) that are selectively operated to allow air to enter and flow through the respective waste tanks **516**, **518**, depending on the mode of operation and the specific configuration of the waste collection and processing system **500**.

[0059] The waste bags **524** may be removable from the respective waste tanks **516**, **518**, and replaceable. In some embodiments, the waste bags **524** are a consumable or disposable element, and in other embodiments, the waste bags **524** may be processed and reused, depending on the specification configuration and application of the system **500**. The waste bags **524** can be removed from the waste tanks **516**, **518** to remove collected solid and/or liquid wastes for disposal outside of the waste collection and processing system **500**. The removal of the waste bags **524** may be based on a fill level of the waste bags **524** or based on a schedule, or some other reason.

[0060] As shown, downstream from the waste tanks **516**, **518** is an air filter assembly **530** for treating air pulled from the waste tanks **516**, **518**. A fan **532** may be used to provide a motive force to pull air from the surrounding environment or space in which the waste collection and processing system **500** into and through the system **500**. The air pulled through the system **500** by the fan **532** may enter through the toilet **506** (e.g., when the lid **510** is open and the first valve **512** is open) and through the waste tanks **516**, **518**. In some embodiments, such as shown, that include the air inlets **528** on the waste tanks **516**, **518**, air may be pulled through such air inlets **528** and through the respective waste tanks **516**, **518**. In either configurations, the air and any gases that mix with the airflow within the waste tanks **516**, **518** may be directed into and through the air filter assembly **530** to generate treated air. The treated air may then be provided into a moisture capture system for water reclamation and/or other processing equipment and/or may be directed back into an occupied space as indicated at system outlet **534**.

[0061] The waste collection and processing system **500** provides for waste collection, similar to that described above, along with additional processing functionality built into the system **500**. The toilet **506** may be configured similar to that shown and described above with respect to FIGS. **1-4**. The toilet **506** may have a geometry designed for directing airflow into and through the bowl **508** and direct waste (gases, liquids, solids) from the human user into the bowl **508** and the rest of the system **500**. The first valve **512**, arranged at an outlet of the bowl **508**, is operable to isolate the toilet **506** from the remainder of the system, which may be provided to enable the various modes of operation, as described herein. The system **500** can include features to enable injection of waste treatment fluid(s) or water for waste treatment and system rinse (e.g., fluid injectors **514**). Various other features may also be implemented in this and the other embodiments described, particularly for systems that incorporate waste bags. The waste bags **524**, as noted above, are selected to be permeable to gas, but are impermeable to liquids and solids, thus allowing for capture of liquid/solid waste, and enabling recapture of gases. In some embodiments, the waste bags **524** may be pretreated bags or containers with chemicals and/or coatings for containing, processing, and otherwise handling waste deposited into the waste bags **524**. In some configurations, treatment of waste at the outlet of the bowl **508** and prior to depositing into the waste tanks **516**, **518** may include a flow over pearls, fluid injection between the bowl **508** and the waste tanks **516**, **518**, and/or fluid injection at the bowl **508** itself as a bowl rinsing mechanism. Other treatments and/or pre-treatment applications and operations may be performed without departing from the scope of the present disclosure.

[0062] In additional to the waste collection, described above, the waste collection and processing system **500** also provides for waste storage and recycling functionality. As shown and noted above, two or more waste tanks **516**, **518** are provided that each contain respective waste bags **524**. The waste bags **524** allow for the capture of solid and liquid waste, but flow-through of gases (e.g., air and humidity). The waste tanks **516**, **518** may be configured to operate on a cycle that is manually controlled or may be controlled by the controller **502**. The operational cycle of the operational states of the waste tanks **516**, **518** is designed such that the functions of each waste tank **516**, **518** is interchanged at an interval that allows for one or more of the waste tanks **516**, **518** (or one or more waste bags **524**) to be collecting waste while the other waste tanks **516**, **518** (or waste bags **524**) in the system **500** are used to reclaim water and other byproducts from the waste and prepare the waste for storage once the waste bag is filled and/or removed from the respective waste tank **516**, **518**. Water reclamation is performed by passing air over or through the waste bags **524**, which allow gaseous water to move through the material of the waste bags **524** and enter into an air stream that flows through the system **500** (e.g., from the bowl **508** and/or the air inlets **528**. The water extracted from the waste may then be removed from the air stream. The waste bags **524** may be removable, and may be configured to be sealable when the waste bags **524** are removed from the respective waste tanks **516**, **518**. Once removed, new or empty replacement waste bags **524** may be installed to replace a removed (e.g., filled) waste bag **524**.

[0063] In some embodiments, the optional heaters **526** may be used to apply heat to the air stream, the waste bags **524**, and/or the waste tanks **516**, **518** to reduce the time required to reclaim water from waste. That is, application of heat from the heaters **526** can cause evaporation of gases and water from the waste collected within the waste bags **524**.

[0064] The waste tanks **516**, **518** may be designed for manual or automated removal of the waste bags **524** after stabilization and water recapture from waste within the waste bags **524**. In some configurations, the waste tanks **516**, **518** may include optional secondary filters and waste capture hardware **536** at the outlet of the respective waste tank **516**, **518**. Furthermore, the waste tanks **516**, **518** may

include optional valves **538** at the outlet thereof, which may be selectively closed to fluidly isolate the respective waste tank **516**, **518**.

[0065] Downstream from the waste tanks **516**, **518**, the waste collection and processing system **500** can include an optional air and humidity processing system or assembly. For example, as shown, the filter assembly **530** may be arranged immediately downstream from the waste tanks **516**, **518**. The filter assembly **530** is configured to condition or otherwise treat air as it leaves the waste tanks **516**, **518**. The fan **532** is provided to create a motive force of a flow of air through the system **500**. In accordance with various embodiments, the **532** **530** may be a variable speed fan, a step speed fan, a single speed fan, or multiple fans of one or more types. Additional hardware at the outlet of the system **500** can be added to reclaim moisture from the air. For example, moisture reclamation systems may include regenerative heat exchangers, heat exchangers that interface with other cooling source(s)/systems, phase separators for use in low-gravity environments to separate condensate from dry air, filters, membranes, chemical beds, or other hardware for air and/or water processing, or the like as will be appreciated by those of skill in the art.

[0066] In the system **500**, during a waste deposit operation, airflow, generated by the fan **532**, pulls the waste into an active or operational waste tank (in this illustration, second waste tank **518**). During the waste deposit operation, and as illustratively shown, the second waste tank **518** is active and open for waste collection, and the first waste tank **516** is closed and able to perform reclamation operations for waste that may be contained in a waste bag **524** within the first waste tank **516**. As such, a flow path of waste and gases will be from the bowl **508**, into the active second waste tank **518**, and then out of the active second waste tank **518**, and inactive first waste tank **516** is isolated from such a flow.

[0067] The active second waste tank **518** is open to the flow because the third valve **522** is open. In contrast, the closed first waste tank **516** is isolated because the second valve **520** is closed. With the first waste tank **516** isolated form the flow, the first waste tank **516** may be operated in a reclamation mode of operation, where waste contained within a waste bag **524** within the first waste tank **516** is treated or processed to extract and reclaim water and/or air, while preparing the waste for storage or disposal. In some configurations, the act of opening the lid **510** for use will actuate the switch **504** to activate the controller **502**, thus limiting the duration that electronics are operated in an ON state.

[0068] The controller **502** is configured to direct the first valve **512** and the third valve **522** to open and to operate the fan **532** to generate a flow of air through the toilet **506**, through the second waste tank **518**, and to the system outlet **534**. In some embodiments, the fan **532** may be a single speed fan or the like, with an on and off state. In other embodiments, the fan **532** may be a multi-speed or variable speed fan, having at least a low speed operation and a high speed operation. When the fan **532** is operated, air flow will cause a flow of air to be directed into and through the active containment tank (i.e., second waste tank **518**). The user will deposit waste into the bowl **508**, and the deposit is captured by the airflow within the bowl **508**. The airflow will carry or cause the waste to move through the first valve **512** and the third valve **522** to enter the active containment tank (i.e., second waste tank **518**), where waste is captured by the waste bag **524** within the second waste tank **518**. The airflow continues to flow through the second waste tank **518** and toward an outlet of the system **500**. The air will exit the active waste tank and be processed or treated in the filter assembly **530** and to the system outlet **534**. Once a user has completed the waste deposit, the lid **510** is closed. When the lid **510** is closed, an optional rinse operation is performed to clean and/or rinse the bowl **508** of the toilet **506**. The rinse fluid can be water, waste treatment fluid(s), cleaning fluid(s), sanitizing or disinfecting fluids, or the like. After closure of the lid **510**, and after an optional rise operation, the waste and rinse fluids maybe pulled out of the toilet **506**. Once the waste and fluids are removed from the toilet **506**, such as after a preset run time for the fan **532**, the first valve **512** and the third valve **522** are closed, and the fan **532** is powered down or set to a low flow state.

[0069] In a waste recycle or reclamation mode of operation of the system **500**, airflow is provided over an optionally heated waste bag **524** in a waste tank **516**, **518**. In some configurations, the waste recycle operation may be performed simultaneously with the waste deposit operation, but performed on the inactive waste tank. The waste recycle operation may be performed to collect moisture from waste and/or cleaning fluids from the waste bags **524**. In the waste recycle operation, the fan **532** is powered on (either by the controller **502** or a fan specific controller) to pull air through the waste tank that is in the reclamation mode of operation. In this operation, the second valve **520** is closed (i.e., no fluid connection between the toilet **506** and the first waste tank **516**. Further, in some configurations of this operation, the third valve **522** may also be closed, resulting in no fluid communication between the toilet **506** and both waste tanks **516**, **518**. The air inlet **528** on the waste tank **516**, **518** that is reclamation mode (or both tanks if not in active use such as during waste deposit) open to allow air flow over the waste bag(s) **524** within the waste tanks **516**, **518**. It will be appreciated that the air inlet **528** on the waste tanks **516**, **518** may be configured as valves, pressure relief valves, solenoid valves, variable orifices, or the like to allow for air to be pulled into and through the waste tanks **516**, **518** to capture moisture that is extracted from waste in the waste bags **524**. In some embodiments, the air inlets **528** may be configured as one-way airflow permeable vents or inlets to allow airflow to constantly be pulled through the respective waste tanks **516**, **518**. Alternatively, or in addition thereto, during the reclamation mode of operation, one or more of the valves **512**, **520**, **522** may be opened (fully or partially) to increase the airflow through the waste bag(s) **524** during the reclamation mode of operation. In some such configurations, the toilet **506** may include vents or the like to allow for an airflow from the toilet **506** to pass through the waste tanks **516**, **518**.

[0070] As noted above, the optional heaters **526** may be provided on the waste tanks **516**, **518**, and/or directly to the waste bags **524**, and/or at the air inlets **528**, and/or at other locations within the system **500**. Application of heat from the heaters **526** may expedite water evaporation from waste within the waste bags **524** and may also provide a mechanism to sanitize the waste contained within the waste bags **524**. As the fan **532** is operated, the induced air flow will carry moisture from the waste through the elements **536**, **538** at the outlet of waste tanks **516**, **518**, through the filter

assembly **530**, and then out of the system **500** at the system outlet **534** (e.g., reintroduced into an occupied space or into moisture capture hardware).

[0071] When full, the waste bags **524** may be removed and replaced with an empty bag. It will be appreciated that being full is not a requirement for removal, as a less-than-full waste bag **524** may also be removed, such as based on a schedule, escaping odors, a maintenance operation, for other reasons or at other appropriate time. When the waste bags **524** are to be removed and replaced with an empty bag, the designated waste tank **516**, **518** may be opened to allow for the removal of the waste bag **524** and any collected/captured waste therein. The waste may be at least partially treated by fluids (e.g., from fluid injector **514**) and/or application of heat from the heaters **526**. That is, the fluids provided from the fluid injector(s) **514** may include chemicals that are selected to kill bacteria, breakdown solids, reduce odor generation, or the like, and thus the fluids may be used both for cleaning/rinsing, and for treating collected waste. Further, as noted above, the heaters **526** may provide sanitizing functionality and/or other thermal processing of the waste within the waste bags **524**. The opening of the waste tanks **516**, **518** may be achieved through manually opening a door or the like, electromechanically operating a door or performing a removal operation, electronically controlling elements or functions of the waste tanks **516**, **518** by the controller **502**, or the like. In some configurations, the waste bags **524** may be configured to automatically seal upon removal from the respective waste tank **516**, **518**. In some embodiments, an automated process may be employed where a filled waste bag **524** is closed up and dropped into a collection bin or the like, and an empty bag is moved into place within the respective waste tank **516**, **518**. As such, direct human interaction with filled waste bags may be avoided. In some waste bag removal operations, the fan **532** may be operated to reduce stagnant air and pull any potential resulting odors through the filter assembly **530** during removal of the waste bag **524** from the waste tank **516**, **518**. Once removed, a new waste bag **524** may be installed in the respective waste tank **516**, **518**.

[0072] As discussed above, one waste tank **516**, **518** will be operated in an active or collection mode and the other waste tank **516**, **518** will be operated in an reclamation mode. In some configurations, the waste tank that is operated in the active or collection mode may be operated in such mode until the waste bag therein reaches a predetermined capacity or is considered full. During this time, the active/collection mode waste tank may also perform reclamation operations when not being used for waste deposit. In some embodiments, the two (or more) waste tanks may be cycled in a pattern, such as after a use, the tanks will change operation, such that waste is deposited into each of the bags in sequence. This operational scheme may provide for improved waste processing and reclamation by increasing the amount of time that a given waste tank is in the reclamation mode of operation, and may prevent build up of untreated waste within a given waste tank. It will be appreciated that other operational schemes may be employed without departing from the scope of the present disclosure.

[0073] Referring now to FIG. **6**, a schematic diagram of a waste collection and processing system **600** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **600** includes a controller **602**, a switch **604**, and a toilet **606** having a bowl **608** and a lid **610**, similar to that shown and described above. Similar to the embodiment of FIG. **5**, at the outlet of the bowl **608** is a selectively operable first valve **612** that is configured to be controlled by the controller **602**. A fluid injector **614** is arranged to inject water, cleaning fluid, waste treatment fluid, or the like, directly into the bowl **608** and/or to be mixed with the waste as it is moves from the bowl **608** to a set of waste tanks **616**, **618** (which may be two or more waste tanks). In this illustrative configuration, at the inlet to the first waste tank **616** is a second valve **620**, and at the inlet to the second waste tank **618** is a third valve **622**. Each waste tank **616**, **618** has a respective (removable/replaceable) waste bag **624** and a heater **626** associated therewith, as described above. Similarly, air inlets **628** may be provided on each waste tank **616**, **618** to enable air throughflow, as described above, which may be configured as vents, valves, or the like. The waste tanks **616**, **618** may be configured to alternate operational modes, such as described with respect to FIG. **5**, and thus a described of the operational modes will not be repeated. However, it will be appreciated that in operation, one waste tank **616**, **618** may be operated in an active/collection mode, and the other waste tank **616**, **618** may be operated in a reclamation mode. Downstream from the waste tanks **616**, **618** is a filter assembly **630**, a first fan **632**, and an outlet **634**. At the outlet **634**, the system may include moisture capture, air quality treatment and processing, or the like, for redirecting air into an occupied space, or may be vented or otherwise used onboard a craft, as described above with respect to FIG. **5**.

[0074] In the waste collection and processing system **600** of FIG. **6**, the system **600** includes a two-stage airflow configuration for providing a motive airflow for waste capture at/in the toilet **606** and a motive airflow for drawing waste (solid, liquid, gas) from the toilet **606** and through the waste tanks **616**, **618** as described above. In this configuration, a relatively low airflow may be induced through the waste tanks **616**, **618** during collection of waste while a relatively higher airflow is induced within or at the human interface where waste is deposited (e.g., at the toilet **606**). The waste collection and processing system **600** includes waste capture airflow system **636** which includes a second fan **638**. The waste capture airflow system **636** is integrated with the toilet **606** such that the second fan **638** can generate a flow of air through the bowl **608** in a direction of the first valve **612** to aid in capturing and directing human waste from a user into the system for capture, collection, and processing. A relatively higher or increased airflow rate may be required to direct and/or waste during the waste deposit/capture phase. In contrast, during the reclamation phase, airflow is only required to ensure relatively dry air is provided and supplied into contact with the waste and/or waste bag within the waste tanks **616**, **618**. In accordance with some embodiments, the lower flow rate of the reclamation phase may be significantly lower than that of the deposit/capture phase. However, it will be appreciated that in some embodiments, a relatively high airflow rate may be employed during reclamation (i.e., a single speed fan or the like). In such configurations, the higher flow rate of the reclamation may result in higher power requirements and more noise (e.g., single speed fan capable of deposit/capture), which may be undesirable. Therefore, higher airflow rates are typically reserved for when such flow rates are functionally required (i.e., during capture/deposit). For example, and without limitation, the capture airflow rate

may be 2-10 times greater than the reclamation airflow rate. In some non-limiting embodiments, the capture/deposit airflow rate may be about 15-30 cubic feet per minute (CFM) and the reclamation airflow rate may be about 5 CFM.

[0075] When using the waste collection and processing system **600** during a waste deposit operation, airflow from the waste capture airflow system **636** directs human waste from the user toward an outlet of the bowl **608** and into the currently active waste tank **616**, **618** (i.e., the one in active or collection mode), while the other waste tank **616**, **618** may be operated in the reclamation mode of operation. For example, by opening the lid **610**, the switch **604** may be activated to activate the controller **602** which in turn may activate the waste capture airflow system **636**. The controller **602** may be configured to direct the first valve **612** and the third valve **622** (to the active waste tank) to remain closed or only open slightly. The controller **602** activates the second fan **638** (of the waste capture airflow system **636**) to generate a capture airflow **640**. For example, the second fan **638** may be operated a high flow state or an on state, if it is a single speed fan, to generate the capture flow **640**. The capture airflow generated by the second fan **638** will capture and/or direct waste toward the active waste tank **616**, **618**. For example, a user will make a waste deposit, and the waste is captured by the capture airflow **640** within the bowl **608**, thus preventing waste from splashing or otherwise leaving the bowel **604** at the opening with the lid **610**. The capture airflow **640** carries the waste toward an outlet of the bowl **608** (e.g., proximate the first valve **612**). The user will then close the lid **610**. As an optional step, a rinse operation may be performed to rinse the bowl **608** and direct any waste stuck to the bowl **608** to be collected and directed to the waste tank(s) **616**, **618**. The rise operation may include rinsing with water, a waste treatment fluid, a sanitation or cleaning solution, or the like. After the lid **610** is closed, and the optional rinse is performed, the first valve **612** and the third valve **622** are opened. The second valve **620** remains closed due to the first waste tank **616** is operated in the reclamation mode. With the valves **612**, **622** open, the second fan **638** of the airflow capture system **636** may be powered down or transitioned into a low flow state, and the first fan **632** is powered on. Airflow induced through the waste collection and processing system **600** by the first fan **632**, and optionally the second fan **638**, will direct the waste to the active waste tank **618** (in this case). Once the waste is collected in the waste bag **624** of the second waste tank **618**, the first and third valves **612**, **622** are closed, and both fans **632**, **638** are powered down.

[0076] In a waste recycle operation of the waste collection and processing system **600**, airflow is directed over an optionally heated waste bag **624** in the first waste tank **616** which is in the reclamation mode of operation. It is noted that both waste tanks **616**, **618** may be operated in the reclamation mode simultaneous, although individual or separate operation is also possible. It is noted that the reclamation mode may be stopped and one waste tank transitioned into active mode when a user opens the lid **610** or otherwise begins use of the system **600**. The airflow induced by the fans **632**, **638** will cause moisture and gases from waste in the waste bag(s) **624** to be drawn out of the waste bag(s) **624** such that water may be recaptured. In example of such operation, the first fan **632** is powered on (either by the controller **602** or a fan-specific controller). The second and third valves **620**, **622** are closed, such that airflow cannot be pulled through or from the toilet **606**. As such, in this specific example, the second fan **638** may not be operated during this operation. The air inlets **628** on the waste tanks **616**, **618** provide an inlet for air to enter the respective waste tanks **616**, **618**, even with the valves **620**, **622** being closed. The air drawn through the air inlets **628** will flow over the waste bag(s) **624** within the waste tanks **616**, **618**. This airflow will pass over the waste bags **624** and pull moisture and air therefrom. In some configurations, the optional heaters **626** may be activated to expedite water evaporation from waste and sanitize waste within the waste bag(s) **624**. In some configurations, the air inlets **628** on the waste tanks **616**, **618** may be selectively operable (e.g., open and closed) to allow for moisture capture from only one tank at a time. Thus, in some configurations, the air inlets **628** may be configured as solenoid valves or some other active element that can control air to flow into and through the waste tank(s) **616**, **618**. The induced airflow by the first fan **632** will carry the moist air to the outlet **634** of the system **600** (for recirculation and/or moisture recapture).

[0077] In a removal and replacement operation of the waste bags **624**, the waste tanks **616**, **618** may be opened to allow for the removal of the waste bag(s) that contain processed waste. The processed waste is waste that has been collected within the waste bags **624** and had air pulled through to extract gases and moisture therefrom. In some embodiments, the waste may be heated by the heaters **626** to promote evaporation of any water in the waste, and thus the waste bags **624** may contain substantially dehydrated human waste (i.e., the processed waste). In some configurations, the waste bags **624** may be configured to automatically seal upon removal from a respective waste tank **616**, **618**. During the waste bag removal process, one or both of the fans **632**, **638** may be operated to reduce stagnant air and any potential resulting odors during removal of the waste bags **624** from the waste tanks **616**, **618**. After removal of a used or filled waste bag **624**, a new or empty waste bag **624** may be installed. The waste tank **616**, **618**, with the newly installed waste bag **624**, may be switched to the active collection mode of operation, and the other waste tank **616**, **618** may be operated in the reclamation mode of operation.

[0078] Referring now to FIG. **7**, a schematic diagram of a waste collection and processing system **700** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **700** is similar to that shown and described above with respect to FIGS. **5-6**, and thus like features will not be described again. It will be appreciated that features of the configuration of FIG. **7** may also be implemented in combination with features of other embodiments described herein, such as that shown and described with respect to FIGS. **1-4**. As such, the specific configuration illustrated in FIG. **7** is not intended to be limited to the arrangement and components as shown and described, but rather such illustration is for explanatory purposes. In the waste collection and processing system **700**, the system **700** may be used with single use waste bags as opposed to a single large collection bag within each containment/processing tank. That is, each single use waste bag, in this configuration, may be used by a user for depositing waste into the waste bag while allowing for capture and reclamation of gases and liquid (e.g., water).

[0079] As shown in FIG. **7**, a single-use waste bag **702** is shown arranged within a toilet **704** of the system **700**. In this configuration, during waste deposit, a user will place the

single-use waste bag **702** into the toilet **704** and deposit waste therein. The waste collection and processing system **700** may include an airflow capture system similar to that shown and described with respect to FIG. **6**. For example, a system or arrangement similar to the waste capture airflow system **636** of system **600** may be provided to generate a forced airflow into and through the toilet **704** to aid in collection and processing of moisture and/or air, while the solid and liquid human waste may be captured and contained within the single-use waste bag **702**. In some such embodiments, the reusable waste bag **702** may be configured to be used without the toilet **704**. That is, the reusable waste bag **702** may be configured to couple to a valve **703** or other fluid connection interface of the system **700**. In such a configuration, a fan **705** arranged at an outlet **707** of the system **700**, similar to that described above, may provide a motive force to pull the waste and gases from the waste bag **702** and into/through the system **700**. In still other embodiments, the bowl of the toilet **704** may be designed to assist a user with holding the single-use waste bag **702** during a waste deposit, such as providing a housing or frame that supports or holds the single-use waste bag **702**.

[0080] Due to the implementation of the single-use waste bag **702**, waste bags are not required to be installed within waste tanks **706**, **708** of the system **700**. Rather, the waste tanks **706**, **708** may be configured to receive and process captured moisture and ensure separation of air and liquids for recapture and recycling. In other embodiments, each of the waste tanks **706**, **708** may include a removable waste bag similar to the embodiments described above, with such waste bags being used to capture any waste that is not captured by the single-use waste bag **702**. In this illustrative configuration, the waste tanks **706**, **708** are configured with multiple outlets **710**, as compared to the illustrated single outlet configurations shown above. The inclusion of multiple outlets on the waste tanks **706**, **708** can ensure that airflow and fluid flow through the waste tanks **706**, **708** is not obstructed by waste that may make it into the respective waste tanks **706**, **708**. This may be particularly useful for systems that do not include waste bags within the waste tanks. However, it will be appreciated that the multiple outlet configuration shown in FIG. **7** may be used in any of the illustrative embodiments of the present disclosure. For example, in any of the systems of FIGS. **1-6**, the waste tanks may include multiple fluid outlets to ensure desired airflow, moisture capture, and redundancy to avoid blockage of fluid paths by waste or debris that may not be captured by the waste bags within the waste tanks. Accordingly, the use of multiple outlets on the waste tanks is not limited to the single-use waste bag configuration illustrated in FIG. **7**. Although shown with two outlets on each waste tank **706**, **708**, it will be appreciated that any number of outlets may be provided without departing from the scope of the present disclosure.

[0081] Furthermore, it will be appreciated that in the system **700** of FIG. **7**, the waste tanks **706**, **708** may be operated similar to embodiments that include waste bags therein. For example, the waste tanks **706**, **708** may be operated in the above described modes of operation, with an active collection waste tank and a reclamation waste tank, and swapping between these modes. Furthermore, the waste tanks **706**, **708** may be arranged with heaters for causing evaporation of moisture for collection and reuse. Additionally, fluid cleaning, rinsing, and/or sanitation may be used within the bowl **704** and/or the waste tanks **706**, **708**. Downstream from the waste tanks **706**, **708** may be a filter assembly **712** that is configured to filter gases and moisture pulled from the waste tanks **706**, **708**. At the outlet **707** of the system **700** may be various other systems, such as moisture capture systems and hardware and/or an opening to an occupied space (e.g., for circulating breathable air back to a cabin or the like).

[0082] Referring now to FIG. **8**, a schematic diagram of a waste collection and processing system **800** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **800** is similar to that shown and described above with respect to, for example, FIGS. **5-6**, and thus like features will not be described again. Furthermore, the operation of the waste collection and processing system **800** may be similar to any previously described embodiment, including the various modes of operation. The system **800** includes a toilet **802** and associated electronics including a controller **804**. The toilet **802** is arranged to capture and direct human waste through the system **800**. Downstream from the toilet **802** are waste tanks **806**, **808**, which can include optional heaters **810** and air inlets **812**. A fluid injector **814** may be provided to inject water, cleaning fluids, sanitation fluids, or the like, as described above. Air and moisture may be pulled through the system **800**, and waste may be captured within waste bags within the waste tanks **806**, **808**. A fan **816** may be configured to pull air and moisture through a filter assembly **818** and then the treated air and/or moisture may be directed to a system outlet **820** (e.g., additional processing systems and/or circulated back into an occupied space).

[0083] In contrast to the previously described embodiments, in this illustrative configuration, a venting system **822** is provided. The venting system **822** includes one or more fluid connections between the waste tanks **806**, **808** and a low pressure or vacuum pressure system, indicated at vent **824**. In some embodiments, the vent **824** may be an inlet or entry to a stringent air filtration hardware system that is used to aid in performing a sanitization cycle of the system **800**. Such a sanitization cycle may be performed after reclamation is completed. That is, after waste has been captured and processed, the sanitation cycle may be used to ensure that waste, odors, bacteria, and the like are managed in a sanitary fashion.

[0084] In this configuration, the venting system **822** includes respective venting valves **826** on the waste tanks **806**, **808**, which provide a second outlet flow path for air through the system **800**, different from the flow path to the system outlet **820**. For example, when the venting valves **826** are open, a high pressure differential is imposed on the respective waste tank(s) **806**, **808** due to low pressure (e.g., vacuum of space, a vacuum pump, or other low pressure/vacuum assembly). In some embodiments, the venting valves **826** may be controlled by the controller **804**. In other embodiments, a dedicated controller for venting operations may be provided separate from the controller **804** of the reset of the system **800**. In still other configurations, the venting valves **826** may be manually opened. When the venting valves **826** are opened, various other valves may be closed to fluidly isolate the waste tanks **806**, **808** such that when exposed to vacuum, air from a surrounding environment (e.g., occupied space) is not pulled through the system and evacuated from a spacecraft or the like. As such, additional valves, not shown, may be arranged at all inlets/outlets of the

waste tanks **806**, **808** to ensure that only the waste tanks **808**, **806** are exposed to the low pressure or vacuum when the venting valves **826** are opened.

[0085] In one example operation of the venting system **822**, the controller **804** will operate the heaters **810** to bring the waste tank(s) **806**, **808** up to an elevated sanitization temperature for a duration of time to stabilize the waste within the respective waste tank(s) **806**, **808**. This operation may cause release of various gases from the waste in the waste tank(s) **806**, **808** and/or gases that may be released by evaporation of chemicals or the like that are used during a rinse operation or the like. It will be appreciated that any gasses from this portion of the process may need to be vented or undergo additional filtration, as high sanitization temperatures can result in unique hazards being added to the air. As such, by performing the sanitation and venting steps, harmful gases may be vented and removed without risk of such gases being introduced into an occupied space. It will be appreciated that the venting system **822** of system **800** may be incorporated to any of the other configurations and arrangements described herein, or with other systems based thereon. In some embodiments, the sanitation operation may be omitted, and the venting operation may be performed without pre-heating the material within the waste tanks.

[0086] Referring now to FIG. **9**, a schematic diagram of a waste collection and processing system **900** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **900** is similar to that shown and described above, and thus like features will not be described again and various elements are not shown for clarity of illustration. Further, the operation of the waste collection and processing system **900** may be similar to the previously described embodiments. The system **900** includes a toilet **902** fluidly connected to multiple waste tanks **904**, **906** through a fluid connection having one or more valves, fluid injectors, and the like. The operation of the waste tanks **904**, **906** may be substantially similar to the operational modes described above.

[0087] In this illustrative configuration, the waste collection and processing system **900** includes a recapture system **908**. The recapture system **908** is arranged downstream from the waste tanks **904**, **906** of the system **900**. In operation, humid or moist air may be extracted from the waste tanks **904**, **906** by operation of a fan **910** (similar to the above described operations). In this configuration, the air pulled from the waste tanks **904**, **906** will be directed through the recapture system **908**. The air first passes through a condenser **912**, which will reduce the temperature of the air and cause water to condense into water droplets that are carried on the air. The air carrying the water droplets is then directed into a phase separator **914** which is configured to separate the water content from the air, thus generating dry air and liquid water as outputs from the phase separator **914**. The dry air is then passed through an air filter system **916** and may be recycled back into an occupied space or otherwise stored or used (or vented). The liquid portion (e.g., water) is directed from the phase separator **914** to a liquid filter system **918** and may be driven by a pump **920**. The processed water may then be recaptured, recycled, or otherwise reused and/or stored. It will be appreciated that the recapture system **908** may be implemented with any of the embodiments described herein, such that a similar recapture system may be provided downstream from the waste tanks of the other embodiments described herein, and may be provided in combination with a venting system, such as described with respect to FIG. **8**.

[0088] Referring now to FIG. **10**, a schematic diagram of a waste collection and processing system **1000** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **1000** is similar to that shown and described above, and thus like features may not be shown or described again. The operation of the waste collection and processing system **1000** may be similar to the previously described embodiments. The system **1000** includes a toilet **1002** fluidly connected to multiple waste tanks **1004**, **1006** through a fluid connection having one or more valves, fluid injectors, and the like. The operation of the waste tanks **1004**, **1006** may be substantially similar to the operational modes described above.

[0089] In this illustrative configuration, the waste collection and processing system **1000** includes a recapture system **1008**. The recapture system **1008** is arranged downstream from the waste tanks **1004**, **1006** of the system **1000**. In operation, humid or moist air may be extracted from the waste tanks **1004**, **1006** by operation of a fan **1010** (similar to the above described operations). The recapture system **1008** of FIG. **10** may be similar to the system described with respect to FIG. **9**, having a condenser **1012**, a phase separator **1014**, an air filter system **1016**, a liquid filter system **1018**, and a pump **1020** for pumping the liquid portion from the phase separator **1014**.

[0090] In this configuration, downstream from the fan **1010**, and along the air outlet/output from the phase separator **1014**, is a recirculation junction **1022**. The recirculation junction **1022** has a controllable valve **1024** associated therewith. The recirculation junction **1022** is arranged to selectively direct at least a portion of dry air that has been processed through the recapture system **1008** back into the system **1000**. For example, dry and conditioned air may be recirculated from the recapture system **1008**back to the waste tanks **1004**, **1006**. The recirculated air may be used to provide an airflow through the waste tanks **1004**, **1006**, and may provide similar functionality to the air inlets on the waste tanks that is described with respect to other embodiments herein. Further, in some configurations, a combination of air inlets (e.g., FIGS. **5-6**) and recirculated dry air (e.g., FIG. **10**) may be employed without departing from the scope of the present disclosure.

[0091] In some embodiments, and as shown in FIG. **10**, the system **1000** includes an optional regenerative heat exchanger **1026** arranged along the recirculation loop from the phase separator **1014** back to the waste tanks **1004**, **1006**. The regenerative heat exchanger **1026** may be arranged to provide a thermal exchange between the treated, dry air, and the output humid airflow that exits the waste tanks **1004**, **1006**. The regenerative heat exchanger **1026** may be provided to increase an efficiency of the system **1000**. For example, the dry air may pick up heat from the humid air output from the waste tanks **1004**, **1006**, which may be have been heated using heaters, as described above. As the dry air picks up heat, it will cause a reduction in temperature of the humid air that is passed into the condenser **1012** and the phase separator **1014**. Accordingly, the power and operational requirements of the condenser **1012** and/or the phase separator **1014** may be reduced. In some embodiments, the regenerative heat exchanger **1026** may replace the condenser **1012**, and provide the pre-cooling to the humid air before

entering the phase separator **1014**. Additionally, the warmed, dry air that is recirculated back to the waste tanks **1004**, **1006** may improved water pickup in the waste tanks **1004**, **1006**, which can result in increased reclamation rates.

[0092] Referring now to FIG. **11**, a schematic diagram of a waste collection and processing system **1100** in accordance with another embodiment of the present disclosure is shown. The waste collection and processing system **1100** is similar to that shown and described above, and thus like features may not be shown or described again. Furthermore, the operation of the waste collection and processing system **1100** may be similar to the previously described embodiments. The system **1100** includes a toilet **1102** fluidly connected to a first waste tank **1104** and a liquid waste collection system **1106** fluidly connected to a second waste tank **1108** and a third waste tank **1110**. The fluid connections may include one or more valves, fluid injectors, and the like, as described above. The operation of the waste tanks **1104**, **1108**, **1110** may be substantially similar to the operational modes described above.

[0093] In this illustrative configuration, the waste collection and processing system **1100** includes separate waste capture mechanisms, such as similar to the embodiment of FIG. **2**. In this configuration, the toilet **1102** is fluidly connected with a single waste tank **1104** for solid waste collection, which may be functionally similar to various embodiments described herein. The liquid waste collection system **1106** is provided in parallel with the solid waste collection. The liquid waste collection system **1106** is configured similar to the dual waste tank systems shown and described above, but with the dual waste tank system applied to liquid waste capture and processing rather than all waste (e.g., compare with FIGS. **5-9**). The liquid waste collection system **1106** includes a second waste tank **1108** and a third waste tank **1110** which may be alternated in operational modes (e.g., between active/capture and reclamation), as described above. The liquid waste capture of the liquid waste collection system **1106** may be by a funnel, hose, or the like (e.g., as shown in FIG. **2**) or may be a feature integrated into and/or part of the toilet **1102** (e.g., as shown in FIG. **3**). In the hose configuration, as shown, a liquid waste receptacle **1112** may be used which is structurally separate from the toilet **1102**. In other configurations that incorporate a urine capture element as part of the toilet **1102** (e.g., as shown in FIG. **3**), a hose or conduit may be arranged to receive the liquid waste and directed it to the waste tanks **1108**, **1110** (e.g., similar to the fluid connection between the liquid waste receptacle **308** and the waste tank **312** shown in FIG. **3**).

[0094] It will be appreciated that the toilet **1102** may be configured with dual waste tanks, as shown and described above. In such a configuration, the system may include four (or more) separate waste tanks, with at least two for each waste stream (liquid and all other waste). Furthermore, in some embodiments, a two-stage airflow system may be implemented within the toilet **1102** and/or the liquid waste receptacle **1112** of the liquid waste collection system **1106**, such as shown and described with respect to FIG. **6** (waste capture airflow system **636**). Further, in some embodiments, single bag or single-use bag configurations are possible, with the waste bags used similarly as shown and described with respect to FIG. **7**. In such a configuration, the waste tanks **1104**, **1108**, **1110** may be provided with multiple outlets to ensure that the outflow from the respective waste tanks **1104**, **1108**, **1110** does not clog with waste material.

[0095] In some applications, the waste collection and processing systems of the present disclosure may be configured for short duration operations/flights. During short duration operations/flights, the considerations of waste management may be different. For example, waste recycling and recapture may not be a primary focus, as the limited resource availability may not be as impactful on relatively short missions and/or where resupply is readily available. Examples of short duration operations may be missions that last about a month or less, and longer duration operations may be missions of one month or longer.

[0096] Referring now to FIG. **12**, a schematic diagram of a waste collection and processing system **1200** in accordance with another embodiment of the present disclosure is shown. As illustrated, the waste collection and processing system **1200** includes a controller **1202**, a switch **1204**, and a toilet **1206** having a bowl **1208** and a lid **1210**, similar to that shown and described above, and thus the details of which will not be repeated again. At the outlet of the bowl **1208** is a selectively operable first valve **1212** that is configured to be controlled by the controller **1202**. As shown, in this configuration, a single waste tank **1214** with a waste bag **1216** is provided. The system **1200** may include fluid injectors within the bowl **1208** and/or along a flow path from the bowl **1208** to the waste tank **1214**, as shown and described above.

[0097] The system **1200** includes a second valve **1218** that is arranged at an outlet of the waste tank **1214**. Similar to the systems described above, a fan **1220** may be used to pull air through the waste tank **1214** and the waste bag **1216** to extract moisture and/or air from the waste tank **1214**. The extracted air is then pulled (or pushed) through an air filter assembly **1222**, which may include various filters, separators, and the like for removing odors and/or moisture. The fan **1220** may then direct the treated air back to an occupied space **1224** (e.g., cabin or the like) or the treated air may be recycled or redirected back into the bowl **1208** and/or the waste tank **1216** to provide dry, moving air for waste capture and/or waste processing within the waste tank **1214** and waste bag **1216**. In some embodiments, the fan **1220** may be operated only during a waste deposit or reclamation operation (i.e., when in use). However, in other embodiments, the valves **1212**, **1218** may be kept open (or partially open) for continuous cycling of air through the system **1200**. The partial open state of the valves **1212**, **1218** may be selected to allow continuous airflow without providing a strong airflow therethrough, such as to minimize power consumption and/or to minimize release of odors or the like. In some such configurations, when a waste deposit is being made, the fan **1220** may be operated at a high flow rate to pull waste into the bowl **1208** and/or waste tank **1214**, and when not in use by a user, the fan **1220** may be operated at a low flow rate for continuous dry air circulation. In some such configurations, the lid **1210** may be sealed to the bowl **1208**, and the continuous airflow may be substantially closed loop, or air may be pulled into the system **1200** through an air inlet **1226**, as described above. Further, in some configurations, single-use waste bags may be employed, which may be used within or in combination with the toilet **1206**. In such a configuration, the waste tank **1214** may include multiple outlets to ensure blockage does not occur, such as shown FIG. **7**.

[0098] It will be appreciated that the system **1200** of FIG. **12** may also be used for longer duration missions/operations, although such systems may include reclamation, recapture, and recycling components, such as those shown and described above. Further, it will be appreciated that the waste collection and processing systems described herein can be adjusted to perform for a specific mission or operation. For example, a craft may be configured with one of the more complex systems described herein, but not all components may need to be operated at all times.

[0099] As discussed throughout the present disclosure, and in view of the teachings herein, it will be readily appreciated that various features from the specifically described embodiments may be combined with features from other embodiments, or may incorporate features not specifically shown and described. For example, each of the above described configurations may be implemented with disposable waste bags, reusable waste bags, or may be used with single-use waste bags. Furthermore, for example, water reclamation may be implemented in any of the above described embodiments. As such, it will be appreciated that the specific embodiments described herein are for illustrative and explanatory purposes and are not intended to be limited to the specific set of components and arrangements thereof, as illustrated and described.

[0100] Advantageously, embodiments described herein provide for improved waste collection and processing systems. In accordance with some embodiments of the present disclosure, waste collection and processing systems are provided with various mechanisms for waste capture, collection, treatment, processing, and the like, as described herein. Embodiments of the present disclosure provide for improved and more user-friendly waste collection and processing systems that are operable in low-gravity environments, for both short duration and long duration mission. The systems described herein enable reclamation, processing, recycling, and recapture of usable resources that can be extracted from human waste. For example, embodiments of the present disclosure may be configured to recycle or capture moisture from human waste, and thus water supplies may be replenished or the amount of water to be carried may be reduced. Furthermore, advantageously, embodiments of the present disclosure may reduce costs and complexity of human waste management systems for space-based and low-gravity environment applications.

[0101] Further advantages of the present systems may include elimination of the need for pretreating. In current solutions/systems, the addition of pretreating includes a chemical that is added to urine to make the mixed fluid compatible with downstream systems and storage. Such pretreat chemicals may reduce ammonia off-gassing of the waste and solidification of salts and other urine constituents that could harm rotating machinery or block flow paths. The pretreat chemicals may be highly acidic chemicals that are considered a toxic fluid, and thus may drive additional safety considerations and complications. Additionally, pretreating operations and the hardware required to inject/apply the pretreat chemicals may add to the maintenance/operating mass required for the system. Accordingly, advantageously, by eliminating the pretreating of conventional systems, embodiments of the present disclosure may minimize the complexity, mass, volume, and power of the system. Moreover, embodiments of the present disclosure can reduce the amount of human interaction at each step of operation, thus improving sanitation and safety. Additionally, the quantity of consumables associated human waste in low-gravity environments may be reduced through use of the waste tanks, as described herein. These and other advantages and benefits of the systems and processes disclosed herein will be apparent to those of skill in the art in view of the above discussion and description.

[0102] The use of the terms "a", "an", "the", and similar references in the context of description (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or specifically contradicted by context. The modifier "about" used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the particular quantity). All ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other.

[0103] While the present disclosure has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the present disclosure is not limited to such disclosed embodiments. Rather, the present disclosure can be modified to incorporate any number of variations, alterations, substitutions, combinations, sub-combinations, or equivalent arrangements not heretofore described, but which are commensurate with the scope of the present disclosure. Additionally, while various embodiments of the present disclosure have been described, it is to be understood that aspects of the present disclosure may include only some of the described embodiments. Accordingly, the present disclosure is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

What is claimed is:

1. A waste collection and processing system for use in low-gravity environments, the system comprising:

a toilet having a bowl and a lid;

a waste tank having an inlet and an outlet, wherein the bowl of the toilet is fluidly coupled to the inlet of the waste tank;

a waste bag arranged within the waste tank and configured to capture human waste deposited into the waste tank from the toilet bowl, wherein the waste bag is permeable to gases and impermeable to liquid waste and solid waste;

a filter assembly fluidly coupled to the outlet of the waste tank, the filter assembly configured to treat air that passes through the filter assembly;

a first valve operably arranged between the bowl and the waste tank; and

a second valve operably arranged between the waste tank and the filter assembly,

wherein liquid and solid waste is collected within the waste bag and gases are directed through the bowl, the waste bag, the waste tank, into the filter assembly, and then directed to at least one of the bowl and an occupied space.

2. The waste collection and processing system of claim **1**, further comprising a fan arranged to pull air and waste gases through the bowl, into and through the waste bag and waste tank, into and through the filter assembly, and force treated air to at least one of the bowl and the occupied space.

3. The waste collection and processing system of claim **1**, wherein the filter assembly comprises one or more filters and

separators configured to remove odor and moisture from the air and gases received from the waste tank.

4. The waste collection and processing system of claim **1**, wherein the occupied space is part of a spacecraft.

5. The waste collection and processing system of claim **1**, wherein the occupied space is part of a space station.

6. The waste collection and processing system of claim **1**, further comprising a controller configured to control operation of the first valve and the second valve.

7. The waste collection and processing system of claim **6**, wherein the first valve is opened and the second valve is closed during a capture operation.

8. The waste collection and processing system of claim **6**, wherein the first valve is closed and the second valve is opened during a reclamation operation.

9. The waste collection and processing system of claim **8**, further comprising an air inlet arranged on the waste tank, wherein air from the occupied space is pulled through the waste tank from the air inlet during the reclamation operation.

10. The waste collection and processing system of claim **6**, wherein the first valve is in a partially open state and the second valve is opened during a reclamation operation.

11. The waste collection and processing system of claim **1**, further comprising a switch configured to open and close at least the first valve upon actuation of the switch.

12. The waste collection and processing system of claim **11**, wherein the switch is integrated into the toilet such that opening of the lid causes actuation of the switch and opening of the first valve.

13. The waste collection and processing system of claim **11**, further comprising a controller configured to control operation of the first valve and the second valve in response to actuation of the switch.

14. The waste collection and processing system of claim **1**, wherein the waste bag is configured to be removable from the waste tank.

15. The waste collection and processing system of claim **1**, further comprising at least one fluid injector arranged to inject at least one of water, cleaning fluid, and waste treatment fluid into at least one of the bowl and a flow path between the bowl and the waste tank.

16. A method of waste collection and processing in low-gravity environments, the method comprising:

receiving human waste in a toilet having a bowl and a lid;

collecting and directing the human waste from the bowl into a waste bag arranged within a waste tank that is operably connected to the bowl;

capturing liquid waste and solid waste within the waste bag;

directing air and gaseous waste through the waste bag, out of the waste tank, and into a filter assembly;

treating the air and gaseous waste within the filter assembly to generate treated air; and

directing the treated air to at least one of an occupied space and the bowl of the toilet.

17. The method of claim **16**, further comprising injecting at least one of water, cleaning fluid, and waste treatment fluid into at least one of the bowl and a flow path between the bowl and the waste tank.

18. The method of claim **16**, further comprising pulling air through at least one of the bowl and the waste tank using a fan arranged downstream along a flow path from the filter assembly.

19. The method of claim **16**, further comprising:

opening a first valve arranged between the bowl and the waste tank and closing a second valve arranged between the waste tank and the filter assembly during a capture operation; and

opening the second valve and closing the first valve during a reclamation operation.

20. The method of claim **16**, further comprising pulling air through the waste tank from an air inlet on the waste tank to capture waste gas within the waste tank and remove the waste gas from the waste tank.

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