MODULAR EFFLUENT STREAM TREATMENT APPARATUS AND ASSEMBLY METHOD THEREOF

FIELD OF THE INVENTION

The present disclosure relates to an apparatus for treating effluent streams, and more particularly to a modular effluent stream treatment apparatus and an assembly method thereof.

BACKGROUND OF THE INVENTION

In manufacturing, electronics, and chemical engineering industries, such as semiconductor, display panel, solar panel, thin film, and other processes, gaseous pollutants containing a variety of chemical substances harmful to the human body or to the environment are generated, and therefore gas pollutant treatment apparatuses are required. Common types include combustion type, plasma type, water scrubbing type, and catalytic type, and conventional examples include the apparatuses disclosed in U.S. Patent Nos. US 5,769,626A, US 11,512,688B2, US 11,519,401B2, US 11,530,694B2, and U.S. Patent Publication No. US2024/0310041A1.

By way of example, for combustion and wet scrubbing type gas pollutant treatment apparatus frequently used in semiconductor processes, it is necessary to assemble components such as a reactor, a scrubber tower, a gas supply assembly, a fluid supply assembly, a water tank, an electronic control device, and the like, and to complete associated piping, wiring, and enclosure assembly. This involves a large amount of mechanical assembly, fluid pipeline connections, and

electronic wiring, and the overall structure can be complex, making assembly difficult and requiring a large amount of manpower, time, and other costs. Moreover, under the trend of increasingly requiring compact design in size, the density of hardware inside the enclosure is becoming higher and higher, which further increases the difficulty of assembly.

SUMMARY OF THE INVENTION

According to various embodiments of the present disclosure, a modular effluent stream treatment apparatus is provided. The apparatus may include a frame, a pump assembly, a reactor assembly, an electronics and control assembly, a fluid delivery assembly, and a housing. The frame may include a plurality of connecting members connected to one another and a plurality of spaces defined by the connecting members. The spaces may include a first region, a second region adjacent to the first region, and a third region adjacent to the second region. Each of the regions may have an installation opening communicating with an exterior. The pump assembly may be disposed in the first region. The reactor assembly may include an effluent stream guiding device, a first-stage reactor, a second-stage reactor, and a water tank. The effluent stream guiding device may be detachably connected to the first-stage reactor so as to introduce an effluent stream into the first-stage reactor. The water tank may be connected downstream of the first-stage reactor. The second-stage reactor may be connected to the water tank so as to receive the effluent stream having passed through the water tank. In some examples, the reactor assembly

may be detachably connected to the pump assembly and may be disposed in the second region. The electronics and control assembly may be detachably connected to the reactor assembly. The electronics and control assembly may be disposed in the third region. The fluid delivery assembly may be detachably connected to the reactor assembly. The fluid delivery assembly may include a plurality of pipelines configured to deliver cooling water to the reactor assembly, discharge cooling water from the reactor assembly, supply fresh water to the first-stage reactor and/or the second-stage reactor, and provide circulating water to the water tank. The housing may be disposed on the frame to enclose the spaces. The housing may include a plurality of panels detachably attached to the connecting members so as to expose or close the installation openings. In some examples, the panels may include an effluent stream inlet portion, an effluent stream outlet portion, and a gas inlet portion. The effluent stream inlet portion may be connected to the effluent stream guiding device. The effluent stream outlet portion may be connected downstream of the second-stage reactor. The gas inlet portion may be connected to the fluid delivery assembly. The frame may extend along a first lateral direction, a second lateral direction, and a longitudinal direction so as to define a boundary of the apparatus together with the housing. When the panels are removed to expose the installation openings, the pump assembly, the reactor assembly, and the electronics and control assembly may each be laterally inserted through the installation openings into the first region, the second region, and the third region, respectively, to

facilitate placement.

According to various embodiments of the present disclosure, a method for assembling an effluent stream treatment apparatus is provided. The method may include providing a frame including a plurality of connecting members connected to one another and a plurality of spaces defined by the connecting members. The spaces may include a bottom space, a first upper space located above the bottom space, and a second upper space laterally adjacent to the first upper space. Each of the spaces may have an installation opening communicating with an exterior in a lateral direction.

The method may further include introducing a pump assembly, a reactor assembly, and an electronics and control assembly through the installation openings into the bottom space, the first upper space, and the second upper space, respectively. In some implementations, orientations of the reactor assembly, the electronics and control assembly, and the pump assembly when entering the spaces may be independent of one another.

The method may further include connecting one or more additional components to the pump assembly, the reactor assembly, and the electronics and control assembly.

The method may further include detachably attaching a plurality of panels to the frame to close the installation openings, thereby defining an enclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a perspective view of an effluent stream treatment

apparatus according to one embodiment of the present disclosure.

FIG. 2 illustrates a perspective view of the apparatus of FIG. 1 with the housing removed.

FIG. 3 illustrates an exploded perspective view of the frame and the housing according to one or more embodiments of the present disclosure.

FIGS. 4A and 4B illustrate perspective views of the frame according to one or more embodiments of the present disclosure.

FIGS. 5A and 5B illustrate, respectively, a top view and a side view of the frame shown in FIG. 4B.

FIGS. 6A-6H illustrate an example process for assembling the apparatus according to one or more embodiments of the present disclosure.

FIG. 7 illustrates a perspective view of an effluent stream treatment apparatus according to another embodiment of the present disclosure.

FIGS. 8A and 8B illustrate perspective views of the apparatus of FIG. 7 with the housing removed.

FIGS. 9A and 9B illustrate perspective views of the frame according to another embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the present disclosure, the terminology used in the descriptions of various embodiments is for the purpose of describing particular examples only and is not intended to be limiting. Unless the context clearly indicates otherwise, or unless the number of elements is

intentionally limited, the singular forms “a,” “an,” and “the” as used herein also include the plural forms. On the other hand, the terms “comprising” and “including” are intended to be inclusive, meaning that additional elements other than those listed may be present. When an element is described as being “connected” or “coupled” to another element, the element may be directly connected or coupled to the other element, or may be connected or coupled thereto through an intermediate element. When an element of a layer, region, or substrate is described as being “on” another element, it may be directly on the other element or there may be an intermediate element therebetween. In contrast, when an element is described as being “directly on” another element, no intermediate element is present therebetween. In addition, the order of description of the embodiments should not be interpreted as implying that operations or steps must depend on the literal order described, and alternative embodiments may execute steps, operations, methods, and the like in an order different from that described herein. As used herein, an “effluent stream” may include a waste gas stream containing one or more gaseous pollutants.

Effluent stream treatment apparatuses typically include hardware such as gas pipelines, reactors, scrubber towers, water tanks, pumps, pipelines for conveying fluids (such as fuel, air, water, and the like), valves, gas panels, detectors, and electronic control systems. These hardware components are assembled within an enclosure to form a Point-of-Use abatement System. In response to customers’ requirements for space utilization efficiency and considerations such

as maximizing production capacity, the volume occupied by effluent stream treatment apparatuses is increasingly reduced, which correspondingly increases the difficulty of assembly. That is, assembling the hardware components within the enclosure and completing the connections requires a considerable amount of manpower and working time. The effluent stream treatment apparatus disclosed in the present disclosure adopts a modular structural design, which facilitates assembly and can significantly shorten the assembly time and reduce the manpower required.

One aspect of the present disclosure discloses an effluent stream abatement apparatus configured to treat effluent streams generated from processes such as, but not limited to, semiconductor manufacturing, display panel fabrication, solar panel fabrication, and the like. The effluent streams may include, for example, waste gas. FIG. 1 and FIG. 2 show an example of the effluent stream abatement apparatus of the present disclosure. In this example, a combustion and wet scrubbing type waste gas treatment apparatus is provided. In certain examples, the effluent stream treatment apparatus may employ a plasma flame or a flame generated from fuel as a combustion source. Effluent streams generated from a chemical vapor deposition (CVD) process and containing silane (SiH_4), arsine (AsH_3), and/or phosphine (PH_3) may be treated and abated using a combustion and wet scrubbing type effluent stream abatement apparatus. The effluent stream abatement apparatus is not limited to the combustion and wet scrubbing configuration described above. In other examples, the

effluent stream abatement apparatus may be configured as a combustion type effluent stream abatement apparatus, a wet type effluent stream abatement apparatus, a plasma-based effluent stream abatement apparatus, a plasma-assisted effluent stream abatement apparatus, or any combination thereof. For example, for perfluorocompound (PFC) gases (such as CF_4) or other pollutants such as SF_6, NF_3, and N_2O, a plasma type effluent stream treatment apparatus may be used.

FIG. 1 shows an effluent stream treatment apparatus, including an enclosure 10 and a plurality of modules. The enclosure 10 includes a structural frame 101 and a housing 102. The housing 102 includes a plurality of panels, and the housing 102 is detachably mounted to the frame 101. FIG. 2 shows the effluent stream abatement apparatus with the housing 102 removed. The modules include a pump assembly 20, one or more microwave sources 30, a reactor assembly 40, an electronics and control assembly 50, a gas supply system 60, a first fluid delivery assembly 70, and a second fluid delivery assembly 80. In this example, the apparatus is a plasma-assisted combustion and wet scrubbing type effluent stream abatement apparatus including the microwave source 30.

FIG. 3 shows an exploded schematic view of the frame 101 and the housing 102. The housing 102 includes a plurality of removable panels, and the removable panels include a right side panel 1021, a left side panel 1022, a top panel 1023, a front panel 1024, a rear panel 1025, and a bottom panel 1026. In this example, the front panel 1024

serves as an access area and the top panel 1023 serves as a gas inlet and outlet area. The front panel 1024 includes a right portion 1024a and a left portion 1024b. The front panel 1024 may further include one or more mechanical input elements (such as buttons) and an operator interface, such as a display screen and an input interface, or a display screen having an integrated input function, for example a touch screen. The top panel 1023 is provided with an effluent stream inlet portion 1023a, an effluent stream outlet portion 1023b, and a gas inlet portion 1023c. In one example, the panel is further provided with a drainage portion, and the drainage portion is connected to the pump assembly 20.

FIG. 4A shows the structural configuration of the frame 101. The frame 101 may include a plurality of connecting members, which may be in the form of rods. These connecting members are assembled to form a bottom structure 101a, a top structure 101b, and a middle structure 101c. The bottom structure 101a includes a bottom frame 101a-1, and may optionally include one or more bottom crossbars 101a-2. The top structure 101b includes a top frame 101b-1, and may optionally include one or more top crossbars. The middle structure 101c includes a middle frame 101c-1 having a plurality of vertical rods. These vertical rods are erected between the bottom frame 101a-1 and the top frame 101b-1. The frame 101 may further include one or more crossbars connected to the middle frame 101c-1, thereby defining a plurality of regions within the enclosure 10 and a plurality of openings that allow these regions to communicate with the exterior.

Referring to FIG. 4B, a plurality of spaces 110 are defined within the enclosure 10, which may be compartment-like regions. The spaces 110 include a first bottom space 1101, a second bottom space 1102, a third space 1103, a fourth space 1104, and a top space 1105. These spaces may be cuboids of different sizes and are adjacent to each other, forming a compact spatial configuration. It should be understood, however, that the depiction of the spaces as cuboids is provided for ease of description and illustration only, and is not intended to limit the spaces to any particular geometric shape. In practice, the spaces may be defined by the structural arrangement within the apparatus and need not conform to a specific geometric form. In some examples, the third space 1103 and the fourth space 1104 are respectively located above the first bottom space 1101 and the second bottom space 1102 and are adjacent to each other in a longitudinal direction (Z-axis direction). The third space 1103 is adjacent to the fourth space 1104 in a lateral direction (X-axis direction). The top space 1105 is located above the fourth space 1104 and is adjacent thereto in the longitudinal direction (Z-axis direction), and the top space 1105 is adjacent to the third space 1103 in the lateral direction (X-axis direction). The right portion 1024a of the front panel 1024 corresponds to the first bottom space 1101 and the third space 1103, and the left portion 1024b corresponds to the second bottom space 1102, the fourth space 1104, and the top space 1105.

In this example, the frame 101 is in a cubic configuration, and has a top face 10a, a bottom face 10b, a front face 10c, a rear face 10d, a

left face 10e, and a right face 10f, as shown in FIG. 5A and FIG. 5B. The frame 101 has a first length L1, a second length L2, and a third length L3. Referring also to FIG. 4A, the crossbars of the frame 101 include a first crossbar 101d-1, a second crossbar 101d-2, a third crossbar 101d-3, a fourth crossbar 101d-4, a fifth crossbar 101d-5, and a sixth crossbar 101d-6. The first crossbar 101d-1 and the second crossbar 101d-2 are disposed at lower portions of the front face 10c and the rear face 10d respectively. The third crossbar 101d-3 and the fourth crossbar 101d-4 are disposed at upper portions of the front face 10c and the rear face 10d. The fifth crossbar 101d-5 is mounted on the first crossbar 101d-1 and the second crossbar 101d-2. The fifth crossbar 101d-5 is located between the left face 10e and the right face 10f, and is close to the right face 10f. The sixth crossbar 101d-6 is located at the left face 10e and is mounted on the middle frame 101c-1.

The first bottom space 1101, the second bottom space 1102, the third space 1103, the fourth space 1104, and the top space 1105 each have a length in the Y-axis direction extending from the front face 10c to the rear face 10d, which is approximately equal to the second length L2. The lengths of the first bottom space 1101, the second bottom space 1102, the third space 1103, and the fourth space 1104 in the X-axis direction respectively extend from the right face 10f or the left face 10e to between 30% and 70% of the first length L1. The length may vary according to different designs, and for example may also range between 20% and 80%. In this example, it is approximately

between 45% and 55%. The lengths of the first bottom space 1101 and the second bottom space 1102 in the X-axis direction may be complementary to each other. The lengths of the third space 1103 and the fourth space 1104 in the X-axis direction may also be complementary to each other. For example, the lengths of the first bottom space 1101 and the second bottom space 1102 may be 45% and 55% of the first length L1, respectively, or may be independent of each other, for example each being 40%. On the other hand, the lengths of the first bottom space 1101 and the third space 1103 in the X-axis direction may be the same or different, and the lengths of the second bottom space 1102 and the fourth space 1104 in the X-axis direction may be the same or different.

The lengths of the first bottom space 1101 and the second bottom space 1102 in the Z-axis direction extend from the bottom face 10b to between 10% and 30% of the third length L3. The length may vary according to different designs, and for example may also range between 5% and 50%. In this example, it is approximately between 10% and 15%. The lengths of the first bottom space 1101 and the second bottom space 1102 in the Z-axis direction may be the same or different. The lengths of the third space 1103 and the fourth space 1104 in the Z-axis direction respectively extend from the tops of the first bottom space 1101 and the second bottom space 1102. The length of the third space 1103 in the Z-axis direction extends to the top face 10a. The length of the fourth space 1104 in the Z-axis direction may terminate between 50% and 90% of the third length L3. The length

may vary according to different designs, and for example may also range between 40% and 95%. In this example, it is approximately between 75% and 85%.

The length of the top space 1105 in the X-axis direction extends from the left face 10e to between 30% and 70% of the first length L1. The length may vary according to different designs, and for example may also range between 20% and 80%. In this example, it is approximately between 45% and 55%. The length of the top space 1105 and the length of the third space 1103 in the X-axis direction may be complementary to each other or may be independent of each other. The length of the top space 1105 in the Z-axis direction extends from the top of the fourth space 1104 to the top face 10a.

The frame 101 further defines a plurality of openings communicating with the respective regions, including a first front opening 1010, a second front opening 1011, a third front opening 1012, a first right opening 1013, a second right opening 1014, a first left opening 1015, a second left opening 1016, a first rear opening 1017, a second rear opening 1018, and a third rear opening 1019.

Referring back to FIG. 2, in the spatial configuration of the modules of the effluent stream abatement apparatus, the components occupying the main volume include the pump assembly 20, the microwave source 30, the reactor assembly 40, the electronics and control assembly 50, and the gas supply system 60. In the present disclosure, the components are arranged as modular units, particularly the pump assembly 20, the microwave source 30, the reactor assembly

40, the electronics and control assembly 50, and the gas supply system 60. The pump assembly 20 is disposed in the first bottom space 1101. The microwave source 30 is disposed in the second bottom space 1102. The reactor assembly 40 is disposed in the third space 1103. The electronics and control assembly 50 is disposed in the fourth space 1104. The gas supply system 60 is disposed in the top space 1105. By coordinating the spatial arrangement of these regions and the positions of these modules relative to each other, a compact structural configuration is achieved. At the same time, by utilizing these openings, assembly personnel or robotic arms can conveniently perform assembly, thereby significantly shortening assembly time and reducing the manpower required.

The connections among these modules involve fluid connections and electrical connections. The pump assembly 20, the microwave source 30, the reactor assembly 40, and the gas supply system 60 may be electrically connected to the electronics and control assembly 50 so as to be controlled by the electronics and control assembly 50. The reactor assembly 40 includes an effluent stream guiding device 41, a first-stage reactor 42, a second-stage reactor 43, and a water tank 44. The first-stage reactor 42 and the second-stage reactor 43 may be disposed on the water tank 44. The effluent stream guiding device 41 may be connected to a manufacturing process tool to receive an effluent stream therefrom and may be disposed above the first-stage reactor 42 so as to guide the effluent stream downward into the first-stage reactor 42. The water tank 44 is connected downstream of the

first-stage reactor 42. The effluent stream flows downward from the first-stage reactor 42 into the water tank 44, and then flows upward from the water tank 44 into the second-stage reactor 43, and is finally discharged from an exhaust port of the second-stage reactor 43.

The first-stage reactor 42 and the second-stage reactor 43 each independently include one or more reaction modules connected to each other. The reaction modules may include, but are not limited to, a combustion reactor, a wet reactor, a plasma combustion reactor, a plasma gasification reactor, and/or a thermal reactor. In this example, the first-stage reactor 42 is a combustion reactor, which may be a plasma combustion reactor or a plasma gasification reactor, and the second-stage reactor 43 is a packed scrubber tower.

In the effluent stream abatement apparatus of this example, the required gases include inert gas (such as nitrogen) and compressed air (CDA), and the required liquids include fresh water and cooling water. The inert gas may be used for opening and closing fluid valves, differential pressure detection, and/or internal gas purging. The compressed air may be used in the plasma reactor. For example, compressed air is plasma-activated and used to impinge upon the effluent stream so as to further decompose the waste gas and/or provide airflow, thereby forming a vortex airflow along the inner wall of a conduit to prevent overheating and damage of the inner wall. In some examples, compressed air may be replaced by inert gas. The gases are connected to the reactor assembly 40 and/or fluid valves via the gas supply system 60 and pipelines. Fresh water is used for the

water curtain of the reactor (the first-stage reactor 42 and/or the second-stage reactor 43) and/or for the water tank 44. Cooling water is used for cooling the reactor assembly 40.

The pump assembly 20 is connected to the water tank 44 of the reactor assembly 40 via one or more pipelines and may be electrically connected to the electronics and control assembly 50. The pump assembly 20 is used for recirculation and/or discharge of water within the water tank 44. The microwave source 30 is connected to one or more plasma modules of the first-stage reactor 42. In this example, there are two microwave sources 30 and two plasma modules, respectively, which may be connected via waveguides or cables. The electronics and control assembly 50 is electrically connected to an external control interface and to one or more of the modules and associated components, for example electrically connected to the pump assembly 20, the microwave source 30, valves and detectors of the reactor assembly 40, the gas supply system 60, and valves and detectors of the first fluid delivery assembly 70 and the second fluid delivery assembly 80.

FIG. 6A to FIG. 6H illustrate the assembly according to this example. As shown in FIG. 6A, the housing 102 is removed from the frame 101 such that the housing 102 is not mounted on the frame 101. Alternatively, the housing 102 may be partially connected to the frame 101 while exposing one or more of the openings. The effluent stream abatement apparatus adopts modular assembly, that is, the pump assembly 20, the microwave source 30, the reactor assembly 40, the

electronics and control assembly 50, the gas supply system 60, and the like may be provided separately as modules. In other words, before being placed into the frame 101, the pump assembly 20, the microwave source 30, the reactor assembly 40, the electronics and control assembly 50, and the gas supply system 60 may not be (physically) connected to each other and may be provided as independent modules. In this example, the bottom panel 1026 is first disposed on the bottom face 10b of the frame 101 and mounted to or fixed to the bottom frame 101a-1. However, it should be understood that, in other examples, two or more of these modules may be pre-connected prior to placement into the frame 101.

Referring to FIG. 6A and FIG. 6B, the pump assembly 20 is laterally inserted into the first bottom space 1101 from the first right opening 1013 (operation O1). The pump assembly 20 may be placed on or fixed to the bottom panel 1026 or the bottom frame 101a-1. The pump assembly 20 may be inserted into the first bottom space 1101 via the first right opening 1013 along the negative X direction, via the first front opening 1010 along the negative Y direction, or via the first rear opening 1017 along the positive Y direction. Alternatively, it may be inserted into the first bottom space 1101 via the first left opening 1015 along the positive X direction.

The microwave source 30 is laterally inserted into the second bottom space 1102 from the first left opening 1015 (operation O2). In this example, the microwave source 30 includes a first microwave source 31 and a second microwave source 32 stacked on each other.

The first microwave source 31 may be placed on or fixed to the bottom panel 1026 or the bottom frame 101a-1, and the second microwave source 32 may be placed on or fixed above the first microwave source 31. The first microwave source 31 and the second microwave source 32 may be supported by a shelf. The shelf may first be mounted or secured to the frame 101 and/or the housing 102, or the first microwave source 31 and the second microwave source 32 may first be mounted or secured to the shelf and then mounted or secured to the frame 101 and/or the housing 102. The microwave source 30 may be inserted into the second bottom space 1102 via the first left opening 1015 along the negative X direction, via the first front opening 1010 along the negative Y direction, or via the first rear opening 1017 along the positive Y direction.

In the reactor assembly 40, the water tank 44 may be a rectangular box and has a front portion 44a and a rear portion 44b. The front portion 44a and the rear portion 44b are respectively disposed adjacent to the front face 10c and the rear face 10d. The first-stage reactor 42 includes two reactors 42a and 42b, which are respectively disposed on the front portion 44a. The second-stage reactor 43 is disposed on the rear portion 44b.

The reactor assembly 40 may be laterally inserted into the third space 1103 from the second right opening 1014 (operation O3). The reactor assembly 40 is located above the pump assembly 20 and may be fixed or mounted to the fifth crossbar 101d-5. FIG. 6C to FIG. 6E show that the reactor assembly 40 is partially and sequentially

assembled in the third space 1103. In FIG. 6C, the water tank 44 is first laterally inserted into the third space 1103 from the second right opening 1014 along the negative X direction and placed on or fixed to the fifth crossbar 101d-5. Then, the first-stage reactor 42 and the second-stage reactor 43 are laterally inserted into the third space 1103 from the second right opening 1014 along the negative X direction and mounted on the water tank 44, as shown in FIG. 6D and FIG. 6E. Thereafter, the effluent stream guiding device 41 is mounted on the first-stage reactor 42 along the negative X direction from the second right opening 1014 or from above, as shown in FIG. 6F. However, in other examples, the reactor assembly 40 may first be fully assembled and then inserted into the third space 1103 via the second right opening 1014 along the negative X direction.

The electronics and control assembly 50 is laterally inserted into a front region of the fourth space 1104 from the second left opening 1016 (operation O4). The electronics and control assembly 50 may include a cabinet 51. A front panel of the cabinet 51 is integrated into the left portion 1024b of the front panel 1024. A side panel 510 of the cabinet 51 is mounted on the middle frame 101c-1 adjacent to the front region of the fourth space 1104. In some examples, the electronics and control assembly 50 may be mounted or fixed to the frame 101 and/or the housing 102 via the cabinet 51, for example via a side structure thereof or structures in other orientations. The electronics and control assembly 50 may be inserted into the front region of the fourth space 1104 via the second left opening 1016 along the positive X direction,

via the second front opening 1011 along the negative Y direction, or via the second rear opening 1018 along the positive Y direction.

The gas supply system 60 is laterally inserted into the top space 1105 from the second left opening 1016 (operation O5). The gas supply system 60 may be a gas panel, including a mounting plate 61 and a gas distribution manifold assembly 62 mounted on the mounting plate 61. The gas distribution manifold assembly 62 may include a gas distribution manifold, a mass flow controller, and a monitoring system. The mounting plate 61 of the gas supply system 60 is mounted on the middle frame 101c-1 adjacent to the top space 1105. In some examples, the gas supply system 60 may be mounted or fixed to the frame 101 and/or the housing 102 via the mounting plate 61, for example via a side structure thereof or structures in other orientations. The gas supply system 60 may be inserted via the second left opening 1016 along the negative X direction or via the second rear opening 1018 and the third rear opening 1019 along the positive Y direction into a rear region of the fourth space 1104.

The first fluid delivery assembly 70 is disposed in a rear region of the fourth space 1104. The second fluid delivery assembly 80 is disposed in a space between the reactor assembly 40 and the right side panel 1021 within the third space 1103.

The first fluid delivery assembly 70 includes a mounting plate 71, a plurality of pipelines 72, 73, 74 disposed on the mounting plate 71, and one or more valves configured to control fluid flow through the pipelines 72, 73, 74. The pipelines 72, 73, 74 are respectively

configured to deliver cooling water into the effluent stream abatement apparatus to the reactor assembly 40, to discharge cooling water of the reactor assembly 40 out of the effluent stream abatement apparatus, and to discharge water from the water tank 44. The second fluid delivery assembly 80 includes a first portion 81 and a second portion 82, which are respectively used to provide fresh water to the first-stage reactor 42 and/or the second-stage reactor 43 and to provide circulating water to the water tank 44.

The first fluid delivery assembly 70 and the second fluid delivery assembly 80 may be installed in various ways. In one example, the first fluid delivery assembly 70 may laterally enter the space 110 from the second left opening 1016 or from the second rear opening 1018, and the mounting plate 71 is mounted on the middle frame 101c-1 adjacent to the rear region of the fourth space 1104. Alternatively, the first fluid delivery assembly 70 may be connected to the reactor assembly 40 and the water tank 44 via the pipelines 72, 73, 74 and fixed or disposed in the rear region of the fourth space 1104.

The second fluid delivery assembly 80 may laterally enter the space 110 (the third space 1103) from the second right opening 1014 or from the second rear opening 1018. The first portion 81 may be mounted on the rear panel 1025, and the second portion 82 may be mounted on the right side panel 1021. It should be understood that the first portion 81 and the second portion 82 may first be mounted on the rear panel 1025 and the right side panel 1021, and then the rear panel 1025 and the right side panel 1021 are mounted on the frame 101,

thereby fixing or disposing the first fluid delivery assembly 70 in the rear region of the fourth space 1104. Alternatively, the first fluid delivery assembly 70 may first be placed into the rear region of the fourth space 1104, and when the rear panel 1025 and the right side panel 1021 are mounted on the frame 101, the first portion 81 and the second portion 82 are then mounted on the rear panel 1025 and the right side panel 1021. Alternatively, the second fluid delivery assembly 80 may be connected via the first portion 81 to the first-stage reactor 42 and/or the second-stage reactor 43, and via the second portion 82 to the water tank 44, and fixed or disposed in the rear region of the fourth space 1104, and then the first portion 81 and the second portion 82 are mounted on the rear panel 1025 and the right side panel 1021.

With respect to inserting the pump assembly 20, the microwave source 30, the reactor assembly 40, the electronics and control assembly 50, and the gas supply system 60 into the enclosure as described above, various sequences may be adopted. In one example, the modules are inserted in the order of operation O1, operation O2, operation O3, operation O4, and operation O5. In other examples, the sequence may be different, for example operation O1, operation O3, operation O2, operation O4, and operation O5, or operation O2, operation O4, operation O1, operation O3, and operation O5. In some examples, certain operations may be performed simultaneously or merged. For example, operation O1 and operation O2 may be performed simultaneously or merged first, followed by operation O3

and operation O4, and then operation O5. In other examples, operation O1, operation O3, operation O2, operation O4, and operation O5 may be performed simultaneously or merged.

After the pump assembly 20, the microwave source 30, the reactor assembly 40, the electronics and control assembly 50, and the gas supply system 60 are placed into the space 110 of the enclosure 10, the first fluid delivery assembly 70 and the second fluid delivery assembly 80 may be attached before the panels are mounted to the frame 101. Alternatively, the first fluid delivery assembly 70 and the second fluid delivery assembly 80 may be attached together with the attachment of the panels. Since the panels are detachably mounted to the frame 101, all or part of the panels may be attached first, and then the first fluid delivery assembly 70 and the second fluid delivery assembly 80 may be attached. Because the first fluid delivery assembly 70 and the second fluid delivery assembly 80 occupy relatively small space, their placement is more flexible.

In this example, the openings of the frame 101 on the rear face 10d, the left face 10e, and the right face 10f serve as installation openings, including the first right opening 1013, the second right opening 1014, the first left opening 1015, the second left opening 1016, the first rear opening 1017, the second rear opening 1018, and the third rear opening 1019. The openings of the frame 101 on the front face 10c may also serve as installation openings and, after assembly, serve as maintenance openings, including the first front opening 1010, the second front opening 1011, and the third front opening 1012.

After the pump assembly 20, the microwave source 30, the reactor assembly 40, the electronics and control assembly 50, the gas supply system 60, the first fluid delivery assembly 70, and the second fluid delivery assembly 80 are placed into the space 110 of the enclosure 10, the right side panel 1021, the left side panel 1022, the top panel 1023, and the rear panel 1025 may be fixed to the frame 101. The fixation herein refers to detachable fixation, for example by using threaded fasteners (such as screws, bolts, studs), insertion-type connectors (such as pins, tenon joints), latching members (such as clips, snap fits), quick-release members, or interlocking members. The fixation between the front panel 1024 and the frame 101 is openable fixation. This is in consideration that when the effluent stream abatement apparatus is completed and operated at a customer’s facility, the right side panel 1021, the left side panel 1022, the top panel 1023, and the rear panel 1025 are less frequently opened, whereas the front panel 1024 is more frequently opened. In one example, the right portion 1024a and the left portion 1024b of the front panel 1024 are respectively a left door panel and a right door panel. Hinges of the left door panel and the right door panel are respectively disposed at a left side and a right end of the frame 101. The left portion 1024b further includes an upper left door panel 1024b-1, a middle left door panel 1024b-2, and a lower left door panel 1024b-3. When the upper left door panel 1024b-1 is opened, the gas supply system 60 is exposed. When the middle left door panel 1024b-2 is opened, the electronics and control assembly 50 is exposed. When the lower left door panel

1024b-3 is opened, the microwave source 30 is exposed. Since the gas supply system 60, the electronics and control assembly 50, and the microwave source 30 involve major electronic units of the effluent stream abatement apparatus, this facilitates maintenance personnel in performing electrical inspection and maintenance via the first front opening 1010, the second front opening 1011, and the third front opening 1012. In one example, when the left portion 1024b is opened, a first maintenance opening is exposed, and when the right portion 1024a is opened, a second maintenance opening is exposed. Any area of the first maintenance opening and the second maintenance opening is not greater than any area of the opening exposed when the left side panel 1022 and the right side panel 1021 are opened or removed.

In this example, the space in which the pump assembly 20 is placed may be referred to as a first region, the space in which the reactor assembly 40 is placed may be referred to as a second region, and the space in which the electronics and control assembly 50 is placed may be referred to as a third region. The first region, the second region, and the third region are respectively the first bottom space 1101, the third space 1103, and the fourth space 1104. In terms of relative position, the first region may be referred to as a bottom space, and the second region and the third region may be respectively referred to as a first upper space and a second upper space. The portions through which the pump assembly 20, the reactor assembly 40, and the electronics and control assembly 50 respectively enter the spaces to facilitate assembly are a first installation opening, a second installation opening,

and a third installation opening. The first installation opening, the second installation opening, and the third installation opening may respectively be the first right opening 1013, the second right opening 1014, and the second left opening 1016.

Referring back to FIG. 6A, during placement of the pump assembly 20, the microwave source 30, the reactor assembly 40, the electronics and control assembly 50, and the gas supply system 60 into the space 110 of the enclosure 10, each of the pump assembly 20, the microwave source 30, the reactor assembly 40, the electronics and control assembly 50, and the gas supply system 60 may have a corresponding orientation and a cross-sectional area in a lateral direction. In this example, the cross-sectional area may be an area projected onto a plane orthogonal to the X-axis, such as A20-X, A30-X, A40-X, A50-X, A60-X, or may be an area projected onto a plane orthogonal to the Y-axis, such as A20-Y, A30-Y, A40-Y, A50-Y, A60-Y. In this example, there are two microwave sources 30, and the areas A30-X and A30-Y refer to the area of either the first microwave source 31 or the second microwave source 32.

In one example, the area A20-X is not greater than the area of the first right opening 1013, the area A30-X is not greater than the area of the first left opening 1015, the area A40-X is not greater than the area of the second right opening 1014, the area A50-X is not greater than the area of the second left opening 1016, and the area A60-X is not greater than the area of the second left opening 1016.

The area A20-Y is not greater than the area of a right portion of the first front opening 1010, the area A30-Y is not greater than the area of a left portion of the first front opening 1010, the area A40-Y is not greater than the area of a right portion of the second front opening 1011, the area A50-Y is not greater than the area of a left portion of the second front opening 1011, and the area A60-Y is not greater than the area of the third front opening 1012.

Accordingly, the pump assembly 20, the microwave source 30, the reactor assembly 40, the electronics and control assembly 50, and the gas supply system 60 may be configured as modular units. Each of these units may be pre-assembled prior to being placed into the space 110 of the frame 101. The units may then be introduced into the space 110 through the openings for assembly, thereby reducing assembly time and reducing the likelihood of assembly errors. Conventional effluent stream treatment apparatuses, for example combustion and water scrubbing type waste gas treatment apparatuses, require at least two assembly personnel and at least five working days to complete assembly of one unit. However, in the embodiments described above, only two assembly personnel and one working day are required to complete assembly of one unit.

Each module has a maximum dimension prior to assembly. Since the module is typically not a complete cube, it may have multiple lengths, widths, and heights. In consideration of being inserted into the space 110 through the openings, a maximum dimension is defined for each module, which refers to the maximum length, maximum width,

and maximum height of the module as measured in space. The pump assembly 20 has a first maximum dimension, and the first maximum dimension includes a first length L20, a first width W20, and a first height H20. The microwave source 30 has a second maximum dimension, and the second maximum dimension includes a second length L30, a second width W30, and a second height H30. The reactor assembly 40 has a third maximum dimension, and the third maximum dimension includes a third length L40, a third width W40, and a third height H40. The electronics and control assembly 50 has a fourth maximum dimension, and the fourth maximum dimension includes a fourth length L50, a fourth width W50, and a fourth height H50. The gas supply system 60 has a fifth maximum dimension, and the fifth maximum dimension includes a fifth length L60, a fifth width W60, and a fifth height H60.

The first length L20 and the first height H20 of the pump assembly 20 are not greater than the first right opening 1013. The second length L30 and the second height H30 of the microwave source 30 are not greater than the first left opening 1015. The third length L40 and the third height H40 of the reactor assembly 40 are not greater than the second right opening 1014. The fourth length L50 and the fourth height H50 of the electronics and control assembly 50 are not greater than the second left opening 1016. The fifth length L60 and the fifth height H60 of the gas supply system 60 are not greater than the second left opening 1016. In one example, the sum of the fourth height H50 of the

electronics and control assembly 50 and the fifth height H60 of the gas supply system 60 is not greater than the second left opening 1016.

FIG. 7 to FIG. 9B show another example of an effluent stream treatment apparatus. In this example, the frame 101 has another configuration. The frame 101 includes a plurality of connecting members, and the connecting members may be rods. These connecting members are assembled to form a bottom structure 101a, a top structure 101b, a middle structure 101c, a first vertical rod 101e-1, a second vertical rod 101e-2, a first crossbar 101g-1, a second crossbar 101g-2, a third crossbar 101g-3, a first partition plate 101f-1, and a second partition plate 101f-2. The space 110 within the enclosure 10 includes a first half portion 110a and a second half portion 110b. It should be understood that the term “half portion” does not mean that the first half portion 110a or the second half portion 110b each constitutes half of the space 110, but is merely used to designate a portion of the space 110. The connecting members partition the space 110 into a plurality of regions. The right side panel 1021 includes a first right side panel 1021a and a second right side panel 1021b. The first half portion 110a is used to accommodate the reactor assembly 40. The second half portion 110b is used to accommodate the pump assembly 20, the microwave source 30, the electronics and control assembly 50, and the gas supply system (not shown in the figures). The second half portion 110b includes a bottom region 110b-1, a first intermediate region 110b-2, a second intermediate region 110b-3, and a top region 110b-4. The openings defined by the frame 101 include a

first front opening 1030, a second front opening 1031, a third front opening 1032, a fourth front opening 1033, a first right opening 1034, a second right opening 1035, a first left opening 1036, a second left opening 1037, a first rear opening 1038, a second rear opening 1039, a third rear opening 1040, and a fourth rear opening 1041.

The pump assembly 20 may be laterally inserted into the bottom region 110b-1 of the second half portion 110b from the first left opening 1036 along the positive X direction, or may be inserted into the bottom region 110b-1 of the second half portion 110b via the second front opening 1031 or the second rear opening 1039.

The microwave source 30 includes a first microwave source 31 and a second microwave source 32 stacked on each other. The microwave source 30 may be laterally inserted into the first intermediate region 110b-2 of the second half portion 110b from the second left opening 1037 along the positive X direction, or may be inserted into the first intermediate region 110b-2 of the second half portion 110b via the third front opening 1032 or the third rear opening 1040.

The reactor assembly 40 includes an effluent stream guiding device 41, a first-stage reactor 42, a second-stage reactor 43, and a water tank 44. In this example, the first-stage reactor 42 includes two reactors 42a and 42b. In this example, the first-stage reactor 42, the second-stage reactor 43, and the water tank 44 may first be assembled together and then laterally inserted into the first half portion 110a from the first right opening 1034 along the negative X direction. Alternatively, the water tank 44 may first be laterally inserted into the

first half portion 110a from the first right opening 1034 along the negative X direction, and then the first-stage reactor 42 and the second-stage reactor 43 are mounted on the water tank 44. Thereafter, the effluent stream guiding device 41 is mounted on the first-stage reactor 42.

The electronics and control assembly 50 may be laterally inserted into the second intermediate region 110b-3 of the second half portion 110b from the second left opening 1037 along the positive X direction, or may be inserted into the second intermediate region 110b-3 of the second half portion 110b via the fourth front opening 1033 or the fourth rear opening 1041.

The gas supply system 60 may be laterally inserted into the top region 110b-4 of the second half portion 110b from the second left opening 1037 along the positive X direction, or may be inserted via other directions.

In summary, the present disclosure provides a configuration in which the pump assembly, the reactor assembly, the electronics and control assembly, the microwave source, and the gas supply system are implemented as modular units, these units may be pre-assembled prior to being placed into the space of the frame, and then placed into the respective spaces through the openings of the frame. This can significantly improve assembly efficiency and solve the problem in conventional effluent stream treatment apparatuses that require a large amount of manpower and assembly time.

What is Claimed is:

1. A modular effluent stream treatment apparatus, comprising:

a frame including a plurality of connecting members connected to each other and a plurality of spaces defined by the connecting members, the spaces including a first region, a second region adjacent to the first region, and a third region adjacent to the second region, the regions each having an installation opening communicating with an exterior;

a pump assembly disposed in the first region;

a reactor assembly including an effluent stream guiding device, a first-stage reactor, a second-stage reactor, and a water tank, wherein the effluent stream guiding device is detachably connected to the first-stage reactor so as to introduce an effluent stream into the first-stage reactor, the water tank is connected downstream of the first-stage reactor, and the second-stage reactor is connected to the water tank so as to receive the effluent stream having passed through the water tank, wherein the reactor assembly is detachably connected to the pump assembly and is disposed in the second region;

an electronics and control assembly detachably connected to the reactor assembly, the electronics and control assembly being disposed in the third region;

a fluid delivery assembly detachably connected to the reactor assembly, the fluid delivery assembly including a plurality of pipelines configured to deliver cooling water to the reactor assembly, discharge cooling water from the reactor assembly, supply fresh water to the first-stage reactor

and/or the second-stage reactor, and provide circulating water to the water tank; and

a housing disposed on the frame to enclose the spaces, the housing including a plurality of panels detachably attached to the connecting members so as to expose or close the installation openings, wherein the panels include an effluent stream inlet portion, an effluent stream outlet portion, and a gas inlet portion, the effluent stream inlet portion being connected to the effluent stream guiding device, the effluent stream outlet portion being connected downstream of the second-stage reactor, and the gas inlet portion being connected to the fluid delivery assembly;

wherein the frame extends along a first lateral direction, a second lateral direction, and a longitudinal direction so as to define a boundary of the apparatus together with the housing; and

wherein the apparatus is configured such that, when the panels are removed to expose the installation openings, the pump assembly, the reactor assembly, and the electronics and control assembly are each laterally inserted through the installation openings into the first region, the second region, and the third region, respectively, for assembly.

2. The apparatus of claim 1, wherein the second region and the third region are laterally adjacent to each other, and the first region is located below the second region.

3. The apparatus of claim 2, wherein the second region and the first region are vertically separated by a spacer, and the spacer supports the water tank of the reactor assembly.

4. The apparatus of claim 2, wherein the first region is a bottom space, and the second region and the third region are respectively a first upper space and a second upper space.
5. The apparatus of claim 3, wherein the panels include a right side panel, a left side panel, a top panel, a front panel, and a rear panel, the right side panel being adjacent to the reactor assembly located in the second region and the pump assembly located in the first region, and the left side panel being adjacent to the electronics and control assembly located in the third region, wherein removal of the right side panel from the frame exposes a first installation opening located below the spacer and a second installation opening located above the spacer, the pump assembly and the reactor assembly being configured to respectively enter the space through the first installation opening and the second installation opening to facilitate assembly therein, and removal of the left side panel from the frame exposes a third installation opening through which the electronics and control assembly enters the respective space to facilitate assembly therein.
6. The apparatus of claim 5, wherein the front panel includes a right portion and a left portion, the right portion being adjacent to the reactor assembly located in the second region and the pump assembly located in the first region, and the left portion being adjacent to the electronics and control assembly located in the third region, wherein removal of the right portion and the left portion from the frame respectively exposes a first maintenance opening and a second maintenance opening, and an area of each of the first maintenance opening and the second maintenance

opening is not greater than an area of each of the second installation opening and the third installation opening.

7. The apparatus of claim 5, wherein the pump assembly has a first maximum dimension including a first length, a first width, and a first height, the reactor assembly has a second maximum dimension including a second length, a second width, and a second height, and the electronics and control assembly has a third maximum dimension including a third length, a third width, and a third height, wherein the first length and the first height of the pump assembly are not greater than the first installation opening, the second length and the second height of the reactor assembly are not greater than the second installation opening, and the third length and the third height of the electronics and control assembly are not greater than the third installation opening.
8. The apparatus of claim 1, wherein the first-stage reactor and the second-stage reactor each independently include one or more reaction modules connected to one another, the reaction modules being selected from the group consisting of a combustion reactor, a wet reactor, a plasma combustion reactor, a plasma gasification reactor, and a thermal reactor.
9. The apparatus of claim 1, wherein the reactor assembly, the electronics and control assembly, and the pump assembly are respectively configured as modular units, each of the modular units having a cross-sectional area in a lateral orientation not greater than the installation opening, such that the modular units are insertable through the installation opening into the first region, the second region, and the third region.

10. A method for assembling an effluent stream treatment apparatus, comprising:

providing a frame including a plurality of connecting members connected to one another and a plurality of spaces defined by the connecting members, the spaces including a bottom space, a first upper space located above the bottom space, and a second upper space laterally adjacent to the first upper space, the spaces each having an installation opening communicating with an exterior in a lateral direction;

respectively introducing a pump assembly, a reactor assembly, and an electronics and control assembly through the installation openings into the bottom space, the first upper space, and the second upper space, wherein orientations of the reactor assembly, the electronics and control assembly, and the pump assembly when entering the spaces are independent of one another;

connecting one or more additional components to the pump assembly, the reactor assembly, and the electronics and control assembly; and

detachably attaching a plurality of panels to the frame to close the installation openings, thereby defining an enclosure.