

REACTOR SYSTEMS

Related Applications

[001] This application claims priority to U.S. Ser. No. 62/799,794 filed on February 1, 2019, which is hereby incorporated herein in its entirety.

Field of the Disclosure

[002] This disclosure relates to the reaction container systems (e.g., reactor systems) providing for headspace-based condensation, coalescing devices, and other features.

Background of the Disclosure

[003] This disclosure relates to devices and methods for the manufacture of chemical and / or biological products such as biopharmaceuticals using reaction containers such as, e.g., multi-use ("MU") and/or disposable containers ("DC", e.g., single-use ("SU")) systems ("reaction container systems"). For instance, fermentors or bioreactors commonly provide a reaction vessel for cultivation of microbial organisms or mammalian, insect, or plant cells to produce such products. Common problems encountered by those using such systems include excessive moisture in the air exhausting therefrom; excess stress being placed on the upper section of a disposable container ("DC"; e.g., a section of continuous film and/or at a seam and/or weld; the headspace section); the need for a separate condenser unit external to the reactor in which a separate DC is contained (e.g., GE's Xcellerex and ThermoFisher's DHX system), requiring additional tubing and pumps and the like (e.g., exhaust tubing); and/or, maintaining the temperature of the reaction mixture within the reactor and/or DC during processing. This disclosure provides improved systems and parts that solve such problems. The systems described herein solve such problems by, for example, condensing fluid from said gas within the headspace (providing a "headspace condenser" or "HC") by providing a lower temperature therein as compared to the portion of the container in which the reaction is carried out, which provides for less load being placed on exhaust filters; including a jacketed and enclosed holder to remove heat across two zones of DC and providing

additional physical support (e.g., a solid surface providing for heat transfer such that the temperature within the headspace is decreased) to the uppermost part of the DC (e.g., the holder dome), thereby relieving pressure thereupon and/or providing higher operating pressure capabilities thereto; directly associating the container (e.g., fermenter) with a coalescing unit such that condensation unit external to the reactor is not required; depositing/returning condensed fluid into the reaction mixture (e.g., passively by gravity) which provides both increased efficiency and additional temperature control; additionally or alternatively removing condensed fluid using cyclonic / mixing / contact forces causing coalescence of condensed vapor particles; and/or reducing the pressure on the DC film using an exhaust pump preferably pulling the exhaust from the headspace from the downstream side of a sterile barrier. This application also addresses problems associated with the use of heat exhaust filters and exhaust gas including moisture. In some embodiments, the exhaust gas is heated with, upon, or prior to entry into heat exhaust filter(s) such that it exhibits a lower relative humidity (RH). Other problems and solutions to the same or other problems are described and/or may be derived from this disclosure, as described below.

Brief Description of the Drawings

[004] **Figure 1.** Exemplary disposable container system. **Fig. 1A** provides a side view of an exemplary system. **Fig. 1B** provides a top view of an exemplary system. **Fig. 1C** provides a side view of another exemplary system. **Fig. 1D** provides a top view of an exemplary system comprising multiple coalescers. **Fig. 1E** provides top view of a system in which the jacketed tank head covers most of the top of a DC including a top seam thereof. **Fig. 1F** provides another side view of a general layout of an exemplary system.

[005] **Figure 2.** **Fig. 2A** provides a view of an exemplary reactor vessel. **Fig. 2B** provides yet another view of an exemplary reactor vessel. **Fig. 2C** provides a top view of an exemplary reactor vessel. **Fig. 2D** provides a side view of an exemplary reactor vessel. **Fig. 2E** provides an additional top view of an exemplary reactor vessel.

[006] **Figure 3** illustrates yet another embodiment of a coalescer of the system.

[007] **Figure 4** illustrates three exemplary embodiments of a low/high pH-compatible fluidic channel adjoined to a polyolefin port.

[008] **Figure 5.** Coalescer and associated tubing connecting coalesce and headspace (second zone) (1); headspace (second zone) surrounded by fluidic channel providing heat transfer, and insulating material (2); first zone with supply tubing and ports at bottom end (3).

[009] **Figure 6.** Exemplary coalescer unit showing interconnected serpentine channels (1), intake tubing (2), exhaust tubing (3), connected sterilizing filters (4), and points at which heat can be introduced into the exhaust gas stream (3A, 3B).

[0010] **Figure 7.** Exemplary disposable reaction system comprising disposable container (DC) (1); DC exhaust line (2); exhaust filter (3); exhaust stream from exhaust filter to environment (4); heated air source ((5), arrows indicate points at which external heated air can be introduced into the exhaust gas).

[0011] **Figure 8.** Exemplary disposable reaction system comprising disposable container (DC) (1); DC exhaust line (2); exhaust filter (3); exhaust stream from exhaust filter to environment (4); heated air source (5); fluidic pathway(s) (6A, 6B); optional, but preferable, sterile filter (7).

[0012] **Figure 9.** Exemplary disposable reaction system comprising disposable container (DC) (1); DC exhaust line (2); exhaust filter (3); exhaust stream from exhaust filter to environment (4); heated air source (5); fluidic pathway(s) (6A, 6B); optional, but preferable, sterile filter (7); filter container (8); and, extension of fluidic pathway 6B into filter container (9).

Summary of the Disclosure

[0013] In some embodiments, this disclosure provides reactions systems and methods for using the same, the systems comprising in some embodiments: at least one exhaust line leading from a disposable reaction container (DC) through which exhaust gas exiting the DC traverses; at least one filter through which the exhaust gas traverses to exit the system; at least one source of external heated air; at least one fluidic pathway connecting the at least one source of external heated air to the at least one exhaust line; and, optionally at least one sterile filter between the at least one source of external heated air to the at least one exhaust line, and at least one second fluidic pathway connecting heated air that exits the sterile filter and the at least one exhaust line. In some embodiments, the external heated air comprises a temperature sufficiently above that of the exhaust gas such that upon mixture of the external heated air and the exhaust gas to produce a mixed exhaust gas, the relative humidity of the mixed exhaust gas is less than that of the exhaust gas. In some embodiments, the relative humidity of the mixed exhaust gas is sufficiently low such that moisture from the mixed exhaust gas does not accumulate on the filter as the mixed exhaust gas exits the system. This disclosure also provides methods for decreasing the relative humidity of an exhaust gas within such reaction system comprising traversing the exhaust gas through such as a system. Other embodiments will be apparent from the disclosure provided herein.

Detailed Description

[0014] This disclosure relates to reaction container systems such as multi-use ("MU") and/or disposable container ("DC", e.g., single-use ("SU")) systems that solve several art-recognized problems, some of which have been described above, and methods for using the same. In some embodiments, the systems may include a reaction vessel, a disposable container (e.g., a single-use disposable container ("SUDC") typically made of a flexible material such as a plastic), one or more filters, and/or one or more exhaust devices. These systems may also include a jacketed tank head, one or more coalescing units contacting the jacketed tank head, one or more additional condensing units, and/or one or more exhaust systems. In some embodiments, this disclosure provides systems and methods for decreasing the relative humidity of an exhaust gas stream produced

during a reaction in a disposable reaction container prior to the exhaust gas stream entering a filter leading to the exterior environment of the reaction system.

[0015] In some embodiments, the system comprises a single use disposable container (DC) comprising a film forming (e.g., surrounding) a headspace ("HS") in the DC which is maintained at a temperature lower than the portion of the DC in which a reaction is carried out (e.g., fluid reactants); and/or, a condenser directly associated with / in contact with the film forming the headspace; and/or a coalescing device enhancing liquid gathering (e.g., collection) and drainage from the headspace. In some embodiments, the DC system may comprise a DC comprising first and second zones; the first zone comprising a reaction mixture maintained at a first temperature; the second zone comprising a HS maintained at a second temperature lower than that of the first temperature, the HS comprising an upper interior surface (adjacent to or opposite an exterior surface) and at least one sidewall; and, a coalescer for collecting fluid condensed in and escaping from the upper interior surface and/or at least one sidewall of the HS. In some embodiments, a heat exchange device contacts the HS and/or is provided within the HS. In some preferred embodiments, the temperature difference may be about 5-10°C (i.e., the first temperature can be 5-10°C warmer than the second temperature or, in other words, the second temperature can be 5-10°C cooler than the first temperature). In some embodiments, such a heat exchange device contacts the sidewall(s) and/or upper interior and/or exterior surface of the HS. In most and preferred embodiments, the DC is surrounded by a reaction vessel, which typically provides support to the DC and other components of the system.

[0016] In operating certain embodiments of the systems described herein, one or more dry gasses (e.g., air, N₂, O₂, CO₂) are introduced into the reaction mixture contained within the DC (the first zone) from the bottom (e.g., through a port positioned in or near the bottom or lower surface of the DC) and traverse through the liquid reaction mixture (e.g., toward) and into the second zone (HS). Along this path, the originally dry gas becomes a humid (or humidified or moist) gas (e.g., a vapor and/or mist). In some embodiments, the humid gas that emerges from the reaction mixture enters and passes

through the second zone (HS), then to a coalescer, and then, typically and optionally, to and through a sterilizing filter. In some embodiments, some of the fluid contained in the humid gas is condensed in the second zone HS by virtue of the temperature difference between the first zone comprising the reaction mixture and the second zone (HS), and the remaining humid gas continues to migrate through and out of the HS and into the coalescer. The condensate collected in the cooled HS may then passively move (e.g., by gravity) back into the reaction mixture (as it is positioned below the HS in the DC), thereby lowering and/or maintaining the temperature of the reaction mixture to and/or at a desired temperature and/or temperature range. The coalescer serves to coalesce, or collect, any additional moisture (e.g., within any remaining humid gas) that has moved out of (or traversed through) the HS. This coalescing may be enhanced by, e.g., a further temperature difference between the HS and the coalescer (e.g., a lower temperature as compared to the HS, such as room temperature environment (e.g., 25°C)) and/or other processes (e.g., cyclonic / mixing / contact forces causing coalescence of condensed vapor particles). The coalescer may also be further cooled (i.e., actively cooled), if desired, to a lower and/or particular temperature by association with (e.g., direct contact with) a heat exchange apparatus, which may be the same or different from that (i.e., heat exchange apparatus) cooling the second zone (HS), and may be and/or comprise, in some embodiments, a jacketed tank head. A further condensing unit may be included in the system, and this condensing unit may have a further lower temperature than either or both of the HS and/or the coalescer.

[0017] For example, in some embodiments, the first zone of the reaction container (i.e., the portion thereof comprising a liquid reaction mixture) may be maintained at an average temperature of 35-40°C (i.e., a first temperature), such as 37°C, while the second zone (i.e., the HS) may be maintained at an average temperature of 30-34°C (i.e., a second temperature) (e.g., 30°C, 32°C, 34°C), and the coalescer may be maintained at a different temperature (e.g., an average temperature of 25°C or room temperature; a third temperature being 5-10°C cooler than the second temperature in the second zone and, accordingly, 10-15°C cooler than the first temperature in the first zone). The temperature of the coalescer may also be affected by the jacketed tank

head, upon which at least part of it typically rests (see, e.g., **Fig. 1B**). The optional further condensing unit described below may provide a further lower average temperature to further assist with condensation of fluid from the moist gas. "Average temperature" refers to the average of the temperature measured at, for instance, three different areas of the compartment of interest since, as would be understood by those of ordinary skill in the art, the temperature at such different areas may vary in the course of a reaction, but together provide an average temperature. The fluid collected in the coalescer may then passively move (e.g., by gravity) back into the second zone (HS), and/or into the first zone (containing the reaction mixture) (e.g., also passively by gravity), thereby lowering and/or maintaining the temperature of the reaction mixture at a desired temperature and/or temperature range. Any remaining gas (i.e., still humid gas), may then move out of the second zone (HS) and/or coalescer, through a filter (e.g., a sterile filter), and exit the system through an exhaust outlet. As described below, in some embodiments, the movement of gas through the headspace, into the coalescer, and out of the system may be assisted by an exhaust pump which, in some embodiments, may include one or more fans.

[0018] In some embodiments, the systems described herein include a reaction vessel. Reactions may be carried out in the reactor vessel per se, or in a container (e.g., a DC) contained within the reaction vessel. The reactions carried out in the systems described herein are typically carried out in a DC. The reaction vessel may take the form of a reaction chamber, fermentor, bioreactor, or the like. The reaction vessel is suitable for chemical reactions, fermentation of microbial organisms, cultivation of cells (e.g., mammalian, insect or plant-based), or other uses. The reaction vessel is typically associated with heat transfer system comprising a heat transfer apparatus for controlling the temperature of a chemical, pharmaceutical or biological process being carried out in within an internal reaction chamber of the vessel. In some embodiments, the heat transfer system provides for distribution of a heat transfer medium such that heat resulting from or required by the process is transferred from or to the reaction mixture. In some embodiments, the reaction vessel comprises a jacket and/or a jacketed tank head that provides a fluidic channel through which a heat transfer fluid may be circulated

(e.g., a dimple jacket). In some embodiments, the reaction vessel may be at least partially surrounded by a fluidic channel. The jacketed tank head may also act as a lid for the reaction vessel. The jacketed tank head may also serve to support and/or relieve pressure on a DC (e.g., on the top of the DC) contained within the reactor vessel.

[0019] In some embodiments, instead of or in addition to a jacketed tank head, a flexible material cover and/or multiple straps (which may be comprised of such a flexible material) may be used to support and/or relieve pressure on the DC (e.g., on the top of the DC) contained within the reactor vessel. In some embodiments, such a flexible material cover and/or straps may be positioned on the DC at one or more positions thereupon that may not be capable of withstanding pressure as well as another one or more positions on the DC (e.g., a seam in the material forming the DC). Straps may, for example, be positioned in a pattern traversing the external surface of the top of the DC in a pattern that supports and/or strengthens that surface (e.g., passing back and forth one or more times across the surface; a crisscross pattern). Such straps may be constructed of any suitable material such as, but not limited to, a fabric, rubber, plastic, metal, and/or combination of the same, and may be flexible or inflexible. The flexible material cover and/or straps are typically affixed to the reactor vessel at one or more positions thereupon (e.g., the interior and/or exterior surface(s) thereof) using one or more connectors and/or brackets (e.g., a tie connector, pipe grip tie). In some embodiments, each of the one or more straps has at least two ends, where each end is affixed (e.g., reversibly affixed) to the reactor vessel through connectors and/or brackets across the top diameter of the reactor vessel such that the strap(s) extends across one or more top diameters of the DC. In some embodiments, the straps may take the form of a net. In some embodiments, the straps form a flat strap cargo net that could cover part of or the entire top surface of the DC, or only those areas of that top surface that experience increased pressure (e.g., where force/pressure would concentrate), or exhibit weakness (e.g., at a seam) as compared to another area that is not subject to such pressure and/or exhibit such relative weakness. In some embodiments, the flexible material may be a light weight, nylon fabric (e.g., “parachute-type” fabric) which can be more conforming to the shape of the DC and less elastic than other materials, thereby

ensuring a proper fit and adequate support. As such, the DC may be able to withstand greater forces (e.g., increased pressure) resulting from certain reactions taking place in the first zone of the DC. Some reactions may produce a volume of gas that produces pressure exceeding the capability of the DC and results in deformation of the DC (e.g., a burst in a seam); the tank head (e.g., jacketed tank head, one or more straps) will provide support for the DC, thereby increasing the pressure capabilities of the system. In some embodiments, it is preferred to use the jacketed tank head, flexible cover, and/or straps to maintain the pressure upon the top surface of the DC at more than 0.1-0.2 pounds per square inch (PSI). In some embodiments, the flexible supports and/or straps can also facilitate the installation process in that these can be removed/retracted easily when the DC is being loaded, and/or installed over the DC to support the load during the operational phase of pressure testing and operation. In some embodiments, the flexible material and/or straps may incorporate a heat transfer function such as by including heat transfer fluid channels or the like within the material thereof. In some embodiments, the support may be built into the DC material, such as between layers of DC material. For instance, one or more materials having greater resistance to pressure than the DC material (e.g., membrane) can be inserted or intertwined between two layers of material that together form the top section of the DC. In some embodiments, the inclusion of such a flexible material cover and/or multiple straps upon or within that top surface provides sufficient support such that fluid transfer to, e.g., another vessel or container) can be carried out without using equipment that is traditionally used with DCs (e.g., a peristaltic pump). In such embodiments, a gas may be introduced into the headspace thereby raising the pressure therein and facilitating fluid transfer. The pressure differential between the vessels controls the rate of liquid transfer. The higher the pressure in the supplying vessel (e.g., the DC) the faster the rate of transfer, assuming the receiving vessel is at atmospheric pressure and the liquid level in the supplying vessel is above the receiving vessel. There is no low limit on pressure as long as it is above atmosphere, and the upper limit is determined by vessel design and how the DC is supported. In some embodiments, then, fluid in the DC (e.g., "below" the headspace within the DC) can thereby be "pushed" out an open port and into another container (e.g., the fluid may be moved from the DC (e.g., bioreactor) and into a

harvesting vessel). Thus, in some embodiments, the systems described herein comprise a disposable reaction container comprising an upper surface adjacent to the second zone comprising a headspace, and a flexible cover and/or straps adjacent to and/or incorporated into the upper surface. In some embodiments, the flexible cover and/or straps comprise at least one heat transfer fluid channel. In some preferred embodiments, the flexible cover and/or straps maintain the pressure upon the top surface of the DC at more than about 0.1-0.2 pounds per square inch (PSI). Accordingly, beyond the heat transfer function, the jacketed tank head, flexible material cover, and/or straps provide additional capabilities, safety and cost advantages to the system.

[0020] The reaction vessels described herein are typically, but not necessarily, constructed of metal and usually, but not necessarily, from a corrosion-resistant alloy. For instance, suitable materials may include, without limitation, sheet / plate stock (and/or dimple-jacket material for, e.g., heat transfer systems). Suitable exemplary materials include, for example, carbon steel, stainless steel (e.g., 304, 304L, 316, 316L, 317, 317L, AL6XN), aluminum, Inconel® (e.g., Inconel 625, Chronin 625, Altemp 625, Haynes 625, Nickelvax 625 and Nicrofer 6020), Incoloy®, Hastelloy (e.g., A, B, B2, B3, B142T, Hybrid-BC1, C, C4, C22, C22HS, C2000, C263, C276, D, G, G2, G3, G30, G50, H9M, N, R235, S, W, X), and Monel®, titanium, Carpenter 20®, among others. It is understood, however, that other materials besides or in addition to a corrosion-resistant alloy such as, but without limitation, plastic, rubber, and mixtures of such materials may also be suitable. A “mixture” of materials may refer to either an actual mixture *per se* to form a combined material or the use of various materials within the system (e.g., an alloy reactor shell and rubber baffle components).

[0021] A DC is typically comprised of a flexible material that is rigid and water impermeable such that a reaction may be carried out within without the DC losing its integrity, and the DC can be disposed of (e.g., removed from the reaction vessel) after use. The DC is physically supported by the reaction vessel and/or associated components, and typically includes and/or is attached to components allowing for

attachment of it to the reaction vessel. The DC is also sealable so that sterile processes may be carried out within the same such that, e.g., failure is not caused by hydraulic forces applied thereto when it is filled with fluid. In some embodiments, the DC may be comprised of a flexible, water impermeable material such as a low-density polyethylene having a thickness in a range between about 0.1 mm to about 5 mm, or other appropriate thickness. The material may be arranged as a single or in multiple layers (e.g., single- or dual-ply). Where a DC comprises multiple layers, it may be comprised of two or more separate layers secured together by, e.g., an adhesive. Exemplary materials and arrangements that may be used include but are not limited to those described in U.S. Pat. Nos. 4,254,169; 4,284,674; 4,397,916; 4,647,483; 4,917,925; 5,004,647; and/or 6,083,587; and/or U.S. Pat. Pub. No. US 2002-0131654 A1. The disposable reaction container may be manufactured to have any desired size (e.g., 10 liters, 30 liters, 100 liters, 250 liters, 500 liters, 750 liters, 1,000 liters, 1,500 liters, 3,000 liters, 5,000 liters, 10,000 liters or other desired volumes).

[0022] The parts of the system (e.g., HS, optional additional coalescing unit, optional further condensing unit, and/or sterile filter) may be connected to one another by welding or other similar processes, or using a flexible material such as tubing (e.g., of a type standard in the industry). Those of ordinary skill in the art would understand such connection techniques.

[0023] The reaction container systems described herein comprise a zone (the second zone) providing a headspace (HS) formed within the container (e.g., a DC) that is continuous with and positioned above (relative to the flow of gas into and out of the system) the first zone in which a reaction is carried out (i.e., the first zone comprises the reaction mixture). The second zone (HS) provides a lower temperature than that present in the first (e.g., that of the reaction mixture). The lower temperature may be provided passively, e.g., by virtue of the temperature of the air surrounding the the DC or HS, but is more typically provided actively using, e.g., a heat exchange apparatus or heat transfer system. The heat transfer systems described herein may be constructed of any material through which heat transfer fluid (e.g., gas and/or liquid) may be

transported such that heat may be conducted to and/or absorbed from another part of the system by radiative, convective, conductive or direct contact. In some embodiments, the heat transfer system may provide a fluidic pathway such as a channel through which heat transfer fluid can flow and/or circulate. The heat transfer systems may be composed of any suitable material, such as e.g., a dimple-jacket material.

[0024] The systems (e.g. reaction systems) described herein provide a reaction container with a first zone comprising a reaction mixture (e.g., an active fermentation reaction) being at or maintained at a high temperature (e.g., 37°C); and a second zone (i.e., the HS), which typically comprises only humid gas and condensed fluid during use, at or maintained at a lower temperature than the first zone (e.g., perhaps only slightly lower such as 34°C but in some embodiments at least about 5°C lower). The reaction container may provide continuous surface along the walls, or it may be separated according to the dimensions of the first and second zones. The reaction container may also be constructed to only contain the first zone, while a separate apparatus is constructed to contain the second zone (e.g., is physically associated with the second zone) (e.g., the combination of heat transfer tubing and insulating material described herein). In some embodiments, the first and/or second zone (HS) are associated with a heat transfer system (HTS) which may be the same or different between the zones. In some embodiments, the temperature difference between the first and second zones may be maintained without associating a heat transfer system with the second zone. In some embodiments, however, the first and second zones (HS) are each associated with the same and/or different heat transfer systems. In some embodiments, the heat transfer system(s) may be what is commonly understood in the art to be “jacket” (e.g., a dimple-jacket material) through which a heat transfer fluid is circulated to provide for the transfer of heat between the first and/or second zones and the heat transfer system(s). In some embodiments, the first and/or second zones may be in contact with (e.g., at least partially surrounded by), the one or more heat transfer systems. In some embodiments, the first and/or second zones may be associated with more than one heat transfer system. For instance, in some embodiments, the second zone may be in contact with more than one jacketed heat transfer system including, for instance, the

aforementioned jacketed tank head. In some embodiments, multiple sets of heat transfer baffles may be included (e.g., one or multiple types and/or arrangements in the first zone and another type or multiple types and/or arrangements in the second zone).

[0025] In some embodiments, the heat exchange apparatus may include one or more of the devices taught in any of, for instance, U.S. Pat. No. 2,973,944 (Etter, et al.), U.S. Pat. No. 3,986,934 (Muller, H.), U.S. Pat. No. 4,670,397 (Wegner, et al.), U.S. Pat. No. 4,985,208 (Sugawara, et al.), U.S. Pat. No. 4,460,278 (Tetsuyuki, et al.), a Platecoil® system, and/or heat transfer baffles such as, for example, that described in U.S. Pat. No. 8,658,419 B2 (Knight, C.; ABEC, Inc.) In some embodiments, the one or more heat transfer systems may comprise, for instance, as described in U.S. Pat. No. 8,658,419 B2, a first sub-assembly consisting essentially of a first material adjoined to a second material to form a first distribution channel; a second sub-assembly consisting essentially of a first material adjoined to a second material to form a second distribution channel; optionally a closure bar that adjoins the first assembly and the second sub-assembly to one another; and, a relief channel between the first sub-assembly and the second sub-assembly; wherein the closure bar, when present, sets the width of the relief channel, and, the distribution channels and the relief channel do not communicate unless a leak forms within a distribution channel. In some embodiments, such a heat transfer baffle may comprise two or more distinct compartments through which heat transfer media may be circulated independently of any other compartment. In some embodiments, such a heat transfer baffle(s) may be adjoined to the interior surface of a reaction vessel, wherein each baffle is adjoined to at least one heat transfer media inlet header and at least one heat transfer media outlet header, and the relief channel of each baffle is vented to the vessel exterior. In some embodiments, the heat transfer baffle(s) may be fixably attached to the interior surface of the reaction vessel at an angle relative to the interior wall or radius of the vessel, the angle being selected from the group consisting of about 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40°, 45°, 50°, 55°, 60°, 65°, 70°, 75°, 80°, 85°, and 90°.

[0026] As mentioned above, in some embodiments, the one or more heat exchange

systems may comprise jacket through which a heat transfer fluid is circulated. The jacket may, for instance, comprises channels through which the heat transfer fluid is circulated. In some embodiments, the jacket may be a “dimpled” material. Dimple jackets are typically installed around reaction vessels such as fermentation tanks and may be used as part of a heat transfer system. Dimple jacket material may be used in the devices described herein in the typical fashion, e.g., wrapped around the reaction vessel. In certain embodiments described herein, dimple jacket material may be also or alternatively used within the baffle structure. Dimple jacket materials are commercially available, and any of such materials may be suitable for use as disclosed here. Typically, dimple jacket materials have a substantially uniform pattern of dimples (e.g., depressions, indentations) pressed or formed into a parent material (e.g., a sheet of metal). Dimple jacket materials may be made mechanically (“mechanical dimple jacket”) or by inflation (e.g., inflated resistance spot welding (RSW)), for example. To prepare a mechanical dimple material, a sheet of metal having a substantially uniform array of dimples pressed into, where each dimple typically contains a center hole, is welded to the parent metal through the center hole. An inflated RSW dimple material (e.g., inflated HTS or H.T.S.) is typically made by resistance spot welding an array of spots on a thin sheet of metal to a more substantial (e.g., thicker) base material (e.g., metal). The edges of the combined material are sealed by welding and the interior is inflated under high pressure until the thin material forms a pattern of dimples. Mechanical dimple materials, when used as jackets, typically have high pressure ratings and low to moderate pressure drop, while RSW dimple jackets typically exhibit moderate pressure ratings and a high to moderate pressure drop. Heat transfer fluid typically flows between the sheets of dimpled material. Other suitable dimple materials are available to those of skill in the art and would be suitable for use as described herein.

[0027] In some embodiments, the heat transfer system (e.g., one or more baffles and/or jackets) may be present across both the first and second zones (e.g., contacting both the reaction mixture and the HS). In such embodiments, the heat transfer system may provide for the cooling of the reaction mixture to a first temperature (e.g., 35-40°C such as 37°C) and the HS to a second temperature lower than the first temperature (e.g., 5°C

or more lower). In some embodiments, such a heat transfer system may only be associated with the first zone or only the second zone (i.e., the HS). In embodiments in which the heat transfer system is only present in the first zone, it serves to maintain the reaction mixture present therein to a first temperature. In such embodiments, the second zone (HS) may be maintained at a second temperature lower than the first temperature with or without using a heat exchange system. In some embodiments, the second zone (HS) may be maintained at a second temperature lower than the first temperature using heat transfer system such as a baffle(s) and/or a jacket(s) separate and distinct from that or those present in the first zone. In some embodiments, the separate and distinct heat transfer systems (e.g., baffle(s) and/or jacket(s) and/or fluidic channel(s) / tubing) may circulate the same or different heat transfer fluids, which may be maintained at the same or different temperatures. For instance, the heat transfer fluid circulating through the heat transfer system (e.g., baffle(s) and/or jacket(s)) present in the first zone may be maintained at a first heat transfer fluid temperature that is warmer or cooler than that circulating through the heat transfer system present in the second zone (HS).

[0028] In some embodiments, the second zone (headspace) may be at least partially surrounded by and directly contacting a heat transfer system such as one or more fluidic channels (e.g., a single piece of tubing, or multiple pieces of tubing) through which heat transfer fluid is circulated. The one or more fluidic channels are also connected to a source of heat transfer fluid by a suitable material (e.g., tubing). In some such embodiments, the reaction vessel may only provide physical support for the DC and/or the fluidic channel and not actually contain the fluidic channel (e.g., the fluidic channel is not positioned within the wall of the reaction vessel). In some embodiments, the fluidic channel may be comprised of a single or multiple channel(s) (e.g., tube having suitable heat transfer capabilities) that wraps around the second zone with spacing between channels varying as desired by the user. In some embodiments, the spacing is constant between each successive level of fluidic channel (e.g., as a fluidic channel transverses horizontally across and from the bottom toward the top of the second zone) and, in others, the spacing is variable between each successive level. In some embodiments,

the spacing may be constant in certain sections of the second zone and variable in other sections of the second zone. In some embodiments, the one or more fluidic channels may be oriented essentially vertically (i.e., extending from the bottom of the second zone (i.e., closest to the top of the first zone) toward the top of the second zone). In some embodiments, fluidic channels may be positioned essentially horizontally as well as essentially vertically. Thus, in some embodiments, certain portions of the second zone will not be in direct contact with a fluidic channel and, in other embodiments, all or substantially all (i.e., 90% or more) of the the second zone will be in direct contact with the one or more fluidic channels. In some embodiments, the fluidic channel may directly contact the second zone (headspace) on one side and an insulating material on the other (i.e., that side of the fluidic channel further from the DC surface). In some such embodiments, the reaction vessel may enclose the first zone but not the second zone. In some embodiments, the one or more fluidic channels may be tubular in shape and comprised suitable heat-conducting material such as, but not limited to, copper. In some such embodiments, the coalescer may also be in direct contact with the one or more fluidic channels, and/or positioned upon the insulating material covering the fluidic channel but through which heat transfer to the coalescer may still be accomplished, above the second zone (see, e.g., coalescer **1** shown in **Fig. 5**). Other arrangements may also be suitable as would be understood by those of ordinary skill in the art.

[0029] Exemplary heat transfer fluids include but are not limited to one or more gasses and/or liquids. Suitable exemplary fluids and gases may include but are not limited to steam (top to bottom), hot and cold water, glycol, heat transfer oils, refrigerants, or other pumpable fluid having a desired operational temperature range. It is also possible to use multiple types of heat transfer media such that, for instance, one type of media is directed to one area of the reaction vessel and another type of media is directed to a different area of the reaction vessel (e.g., as in the zonal system described above). Mixtures of heat transfer media (e.g., 30% glycol) may also be desirable.

[0030] As mentioned above, the systems described herein comprise one or more coalescers for collecting fluid condensed in and escaping from (e.g., moving or migrating

from) the headspace (HS) (i.e., the second zone). The function of the one or more coalescers is typically primarily to channel (or coalesce) smaller fluid droplets into larger fluid droplets. The gas entering the first zone (e.g., through the sparge) is typically a dry gas which becomes a humid gas (or a vapor, understood by those of ordinary skill in the art to be the gas state of a substance coexisting with its liquid) as it moves through the reaction mixture in the first zone. The gas exiting the first zone and entering the second zone (HS) is therefore a fully saturated humidified gas (i.e., this humidified gas, or vapor, has relative humidity of 100% ("fully saturated"); "relative humidity" being defined as a relationship between the actual weight or pressure (content) of water in air at a specific temperature and the maximum weight or pressure (capacity) of water that air can hold at that specific temperature; as compared to "absolute humidity", defined here as the amount of water vapor present in a gas mixture, measured as milligrams of water vapor per liter of air (mg/L ("water vapor content"))). In this fully saturated state, cooling causes the humidified gas to transition into the liquid state (i.e., condense). Thus, the cooler temperature provided by the second zone (HS) condenses the humidified gas into its liquid form. At least some, and in most cases most (i.e., 50, 60, 70, or 80% or more), substantially all (i.e., 90% or more), or all, of the remaining humidified gas will then pass into the coalescer. Since the coalescer is at least partially on (e.g., in contact with) the jacketed tank head that provides heat transfer into the second zone (HS), the temperature within the coalescer will typically be higher than that in the second zone (HS) but is also still typically cooler than that provided by the first zone (i.e., it may be between that of the first and second zones). Thus, some condensation may occur in the coalescer. The primary benefit of the coalescer, however, is to provide increased residency time for the humidified gas as it travels from the disposable reaction container and out into the environment (e.g., through the exhaust vent), and for the collection any additional fluid formed from the humidified gas as it migrated through and from the second zone (HS). The gas exiting the coalescer and entering the filter therefore remains a humidified gas. Stated another way, the humidified gas is not dehumidified in either the second zone (HS) or the coalescer; any fluid collected simply represents a change in state from humidified gas to liquid. Given that some of the humidified gas exiting the first zone, entering and condensing in the second zone, some of which then

enters the coalescer, is collected as fluid, a lesser volume of gas (i.e., the humidified gas) is processed through the filter. The increased residence time provided by the coalescer allows more of the gas that has transitioned into its liquid form to be collected therein prior to encountering the filter. It is noted as well that the filter is typically heated which provides for dehumidification of the gas. The gas which exits the filter and is exhausted into the environment is, therefore, a dehumidified gas.

[0031] Thus, in some embodiments, moisture (i.e., water, water vapor, or water droplets) can be removed from the gas released from the reaction mixture (i.e., the exhaust gas), which is typically at about 37°C as it exits the DC, by cooling it, thereby condensing and coalescing the moist air (e.g., lowering the humidity or dehumidifying the exhaust gas). In some embodiments, that exhaust gas can be passed through one or more heated exhaust filter(s), or preferably heated prior to entering the exhaust filter(s) (that may be heated (e.g., pre-heated) or not heated (e.g., not pre-heated)), to ensure that that exhaust gas has a lower moisture content as it passes through the exhaust filter(s), and will thereby not accumulate thereupon (or therein, such as on the filter material thereof) or, will do so in a lower amount than will unheated (i.e., higher humidity) exhaust gas. In some embodiments, however, the effectiveness of heating the filter to assist with dehumidifying the exhaust gas can be limited due to indirect contact between the heat and the exhaust gas, the limited surface area of the filter that can be heated, and limitations on the temperature to which the filter can be heated. In such situations, the heat that can be transferred into the exhaust filter(s) (e.g., a heated exhaust filter, and/or wherein heat is introduced as the exhaust gas enters the exhaust filter (heated or not heated exhaust filter)) to raise the temperature of the exhaust gas can be insufficient to maintain the relative humidity ("RH", the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at a given temperature) of the exhaust gas sufficiently far from its dew point (i.e., the atmospheric temperature (varying according to pressure and humidity), below which water droplets begin to condense and dew can form), resulting in accumulation of moisture on the filter(s) such that the functionality thereof is less efficient as a filter (or even non-functional). As a solution to such problems, this disclosure provides, in some

embodiments, systems in which “heated external air” directly contacts (i.e., enters the stream of and/or mixes with) the exhaust gas to heat it to a temperature sufficiently above its dew point (i.e., lowering the RH of the exhaust gas) prior to entry into the exhaust filter (e.g., contacting the exhaust filter material or membrane) to ensure that little to no moisture accumulates (or at least less moisture as compared to unheated exhaust gas) on the filter(s) (e.g., exhaust filter material or membrane). The external heated air introduced into the exhaust gas (e.g., the exhaust gas stream) preferably has a temperature above that of the temperature of the exhaust gas as it traverses out of the DC (e.g., the exhaust gas stream) (and then, in some embodiments, into a coalescer), and high enough (e.g., sufficiently above the temperature of the exhaust gas) to raise the temperature of the exhaust gas, upon mixing with it, to a point sufficiently above its dew point such that moisture contained therein does not accumulate on the exhaust filter(s) (e.g., exhaust filter material or membrane), or at least decreasing the amount of such moisture that accumulates thereupon. As such, the heated external air serves to evaporate moisture present in the exhaust gas, thereby lowering the RH thereof. For instance, and for illustrative purposes only, raising the temperature of a saturated exhaust gas (i.e., 100% humidity) from 37°C to 40°C degrees will lower the relative humidity (RH) thereof to 88%; raising the temperature of a saturated exhaust gas from 37°C to 50°C will lower the RH thereof to 54%; and raising the temperature of a saturated exhaust gas from 37°C to 60°C will lower RH thereof to 35%. Raising the temperature of the exhaust gas to above 60°C may also be suitable depending on the particular application. The temperature of the exhaust gas can be controlled using heated external air having a particular temperature. For instance, exhaust gas exhibiting a higher temperature (e.g., 50°C) would require less external heated air, or would require external heated air having a lower temperature, or both, than exhaust gas exhibiting a lower temperature (e.g., 40°C) to achieve the same mixed temperature and RH. Thus, the external air is typically heated to a temperature above the exhaust gas target temperature prior to mixing it with the exhaust gas (e.g., introducing it into the exhaust air) such that the mixture exhibits a temperature higher than that of the exhaust gas as the same exited the DC (and in some embodiments the coalescer), and below that of the external heated air. For instance, one of ordinary skill in the art would

determine a sufficient volume of external heated air having a temperature of 60°C that would need to be introduced into exhaust gas having a temperature of about 40°C to produce an exhaust stream (i.e., exhaust gas that has been mixed with external heated air) having a target temperature set of, for example, 50°C. In some embodiments, the external heated air can be introduced into the exhaust gas at a higher temperature than might be necessary to reach a target temperature for a mixture of equal volumes of external heated air and exhaust gas and then bleeding the external heated air into the exhaust gas at a ratio of less than 1:1, thereby raising the temperature of the exhaust gas to the target temperature while using a lower volume of external heated air. The heat (e.g., as external heated air) can be introduced into the exhaust gas at any point during its transit from the DC to the exhaust filter(s). For instance, in embodiments in which the reactor system includes a coalescer, the heat can be introduced as heated external air at some point after the gas leaves the DC and enters the coalescer, but more preferably after the gas leaves the coalescer and before the gas enters the exhaust filter(s) (e.g., at or near **3A** and/or **3B** in **FIG. 6**). In preferred embodiments, the external heat can be introduced into the exhaust gas stream exiting the coalescer (**1** in **Fig. 6**), and prior to reaching the exhaust filter(s), such that the temperature of the exhaust gas is raised, e.g., to sufficiently above its dew point and to a lower RH, prior to entry into the exhaust filter (e.g., contacting the exhaust filter material or membrane) to ensure that little to no moisture accumulates (or at least less moisture as compared to unheated exhaust gas) on the filter(s) (e.g., exhaust filter material or membrane) (see **Fig. 6**, at or near **3A**). In some preferred embodiments, the external heat can be introduced into the connection (e.g., tubular connection) at any suitable point between the coalescer and the exhaust filter (e.g., **3** in **Fig. 6**).

[0032] In some embodiments, such as those in which a coalescer is not included in the system, the external heated air is introduced into the exhaust gas after the same leaves the DC and before it contacts the exhaust filter(s) (e.g., **FIG. 7**). As illustrated in **FIG. 7**, in some embodiments, the reactor system can include a DC (1) and an exhaust line (2) through which exhaust air leaves the DC and moves toward the filter (3) before being deposited into the external environment (4). In this illustrative embodiment, external

heated air from a source (5) can be introduced into the exhaust air at any point as it traverses the exhaust line (2), and/or into the filter container (3). This is represented by the arrows extending from the source of heated air (5) (e.g., an electric or other air heating unit) to any one or more of several points in exhaust line (2), and/or the filter container (3), immediately prior to the point at which the exhaust gas contacts the exhaust filter or the exhaust filter per se. Thus, in some embodiments, hot external air, which can be but is not necessarily sterile air, can be introduced (e.g., pumped) into the exhaust gas that has exited the DC (i.e., the exhaust stream) to raise and maintain its temperature above that at which it is at it exits the DC to ensure materials condense beyond the sterile boundary. In some embodiments, the heated external air (e.g., which can be sterile air) can be created by passing air across an electric heater or equivalent thereof (e.g., 5 in **FIG. 7**) to create external heated air at a temperature within the operating capabilities of the DC and/or other single use bioprocess equipment, and then introducing that heated air into the exhaust gas (e.g., exhaust gas stream).

[0033] In some embodiments, the external heated air can be introduced into the exhaust stream (i.e., exhaust gas) by connecting a fluidic channel (e.g., tubing), preferably an optionally open or closed fluidic channel (e.g., by including a valve such as a ball or pneumatic valve), to the fluidic channel (e.g., tubing) through which the exhaust air is moving. In some embodiments, that heated air can be passed through a filter (e.g., a sterile filter) before being introduced into the exhaust (e.g., moist) air. In some embodiments, heated air can be introduced into the exhaust line on the sterile side of the exhaust filter to directly heat the exhaust (i.e., moist) air. In some embodiments, heated air can be introduced through the non-sterile side of the exhaust filter to heat the exhaust (i.e., moist) air before it traverses a hydrophobic sterile filter (thereby creating sterile heated air). In some embodiments, the exhaust air can be heated directly as it traverses a fluidic pathway such as tubing (e.g., **2** (i.e., between the DC and the coalescer) or **3** (i.e., connection (e.g., tubular connection) between the coalescer and the exhaust filter) in **FIG. 6**; **6A** and/or **6B** in **FIG. 8**). As shown in **FIG. 8**, in some embodiments the external heated air can flow through an optional, but preferable, sterile filter (**7**) (from external heated air source (**5**), through fluidic pathway **6A** connected

to optional, but preferable, (7), through optional, but preferable, sterile filter (7) and into fluidic pathway **6B**, and into filter container (8)). As shown in **FIG. 9**, in some embodiments the fluidic pathway (6B) through which the external heated air is introduced into the exhaust gas stream extends into a filter container (8) in which filter (3) can be housed. The exhaust gas which exits the filter (3), having been treated as described above, is exhausted into the environment as a dehumidified gas (4). It is noted that these systems for heating the exhaust stream may also be used in systems that lack a coalescer.

[0034] Thus, in some embodiments, this disclosure provides a system having: at least one exhaust line leading from a disposable reaction container (DC) through which exhaust gas exiting the DC traverses; at least one filter through which the exhaust gas traverses to exit the system; at least one source of external heated air; at least one fluidic pathway connecting the at least one source of external heated air to the at least one exhaust line; and, optionally but preferably at least one sterile filter between the at least one source of external heated air to the at least one exhaust line, and at least one second fluidic pathway connecting heated air that exits the sterile filter and the at least one exhaust line. In some embodiments, the external heated air comprises or produces but introduces air having a temperature sufficiently above that of the exhaust gas such that upon mixture of the external heated air and the exhaust gas to produce a mixed exhaust gas, the relative humidity of the mixed exhaust gas is less than that of the exhaust gas. In some embodiments, the relative humidity of the mixed exhaust gas is sufficiently low (e.g., and raising the temperature thereof sufficiently above its dew point) such that moisture from the mixed exhaust gas does not accumulate on the filter as the mixed exhaust gas exits the system. This disclosure also provides methods for decreasing the relative humidity (e.g., and raising the temperature thereof sufficiently above its dew point) of an exhaust gas within such reaction system comprising traversing the exhaust gas (e.g., as a mixed exhaust gas) through such a system (e.g., as illustrated in any of **FIGS. 6-9**).

[0035] The one or more coalescer(s) is/are typically positioned on top of the reaction

vessel such as on top of the jacketed tank head (see, e.g., **Fig. 1B**, **Fig. 1D**, **Fig. 5**). Typically, but not necessarily, the one or more coalescers do not provide significant heat exchange and/or condensation. Heat exchange across the top of the headspace (second zone **5**) is typically primarily provided by the jacketed tank head. In some embodiments, the jacketed tank head may provide heat transfer to the one or more coalescers since the same are positioned upon the jacketed tank head. The one or more coalescers may comprise an upper and a lower surface. The lower surface of each coalescer contacts (is on) the jacketed tank head, typically over some (e.g., at least about 10, 20, 25%, or more) of the surface area of the lower surface of the coalescer. In some embodiments, the lower surface of each coalescer contacts the jacketed tank head over at least about any of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, or up to 100% of its surface area.

[0036] The one or more coalescers typically comprise tortuous and/or sinusoidal fluidic pathway (a “fluidic pathway” being an area through which a fluid may move) extending throughout or substantially throughout, e.g., greater than 50% of the interior portion of, the coalescer. In some embodiments, the one or more coalescers may comprise or may be a container (e.g., a flexible container) comprising one or more fluid channel(s) providing, e.g., a tortuous and/or sinusoidal fluid pathway within the coalescer. As described above, this tortuous and/or sinusoidal fluid pathway provides for increased residence time of the humidified gas and increased collection of fluid. In some embodiments, the coalescer may be a flexible bag composed (or made) of a material suitable for use in a DC (e.g., a sterilizable, flexible water impermeable material such as a low-density polyethylene or the like, having a suitable thickness such as, e.g., between about 0.1 to 5 mm (e.g., 0.2 mm)). In some such embodiments, the coalescer may be produced by fusing at least two sheets of such flexible material together to provide an interior volume using standard techniques in the art. The turns of the tortuous and/or sinusoidal fluid pathway may be provided within that interior volume using similar techniques, e.g., fusing the flexible sheets together in a manner that provides a continuous fluidic pathway (e.g., channel) within the interior chamber thereof. In some embodiments, one or more of the coalescers may provide or may be a flexible, semi-

rigid, or rigid tubular pathway (e.g., a tube) providing for cyclonic removal of gas from the headspace.

[0037] In some embodiments, the coalescer may also comprise, or be connected and/or attached to a device comprising mesh and/or packed solids (e.g., an “anti-foaming device”, as described in US Pat. Pub. No. 2016-0272931 A1 (Rudolph, et al.)) Such a device may be positioned, e.g., between the DC and the one or more coalescer(s) such that humidified gas passes through the anti-foaming device before entering the one or more coalescers, between coalescers, within a coalescer, or between a coalescer and any other part of the systems described herein (e.g., a filter). In some embodiments, and as described in US Pat. Pub. No. 2016-0272931 A1, the anti-foaming device may comprise a container, the interior volume of which may include static mixer and/or granules (e.g., tortuous path) that collapse the foam (e.g., in the form of bubbles) that enters the anti-foaming device. The anti-foaming device typically includes an inlet receiving surface and a venting surface positioned opposite one another on either side of the chamber. The tortuous pathway is found within the chamber between the inlet surface and the venting surface of the anti-foaming device. The chamber may be in the form of tubing (e.g., plastic tubing), for example. Each of the gas inlet surface and the venting surface may be comprised of a material (e.g., a porous and / or mesh material) which serves to retain the granules. The material comprising the surfaces of the same may thus serve to compartmentalize the granules, thereby forming a container. In some embodiments, the anti-foaming device may be contained within a portion of tubing connected to the DC between the exhaust port at the top of the DC and before the exhaust. In such embodiments, the anti-foaming device does not necessarily need to form a completely separate piece of equipment but may instead exist within a piece of tubing through which the humid gas and/or fluid migrates out of the second zone (HS). In such embodiments, the anti-foaming device may be formed by positioning the material at either ends of a section of tubing that contains a tortuous fluidic pathway. One piece of said material may be positioned within the tubing to be proximal to the DC and distal to the vent, and function as a gas stream receiving surface. Another piece of material may be positioned within the tubing to be proximal to the vent and distal to the

DC, and function as a venting surface. The tortuous fluidic pathway is thereby positioned between the gas stream receiving surface and the venting surface. In some embodiments, the tortuous fluidic pathway, the tubing, the material, and / or the DC are composed of substantially the same material. Alternatively, the anti-foaming device may be manufactured and then inserted into the tubing, for instance. In some such embodiments, humid gas migrating from the second zone (HS) encounters the anti-foaming device before entering the coalescer (e.g., the anti-foaming device is positioned between the second zone (HS) and the coalescer, and provides a gas outlet). A system may comprise one or more than one of such devices, e.g., a single device attached to the single coalescer of the system, multiple devices attached to the one or each one of the coalescer(s) of the system, and/or single individual devices being attached to multiple and/or each of multiple coalescers of the system. In some embodiments, then, the system may comprise a DC comprising a second zone (HS) from which the humid gas migrates through this device and into the coalescer. Other embodiments may also be suitable, as would be understood by those of ordinary skill in the art.

[0038] As described above, the humid gas (e.g., vapor, mist) passes from second zone (HS) into the coalescer through one or more fluidic pathways (e.g., tubes) connecting second zone (HS) and the coalescer. In some embodiments, such fluidic pathways may comprise, e.g., screens and/or other additional features (e.g., tubes) such that the nominal cross-sectional area in which the gas travels (e.g., as exhaust) would not create a substantial pressure drop. These fluidic pathways may also be or comprise and/or be associated with one or more input and/or output ports.

[0039] Thus, the coalescers described herein typically comprise one or more fluidic pathways (e.g., channel(s)) providing, e.g., a tortuous and/or sinusoidal fluid pathway, extending throughout, or substantially throughout. The coalescer is also typically connected to one or more input port(s) (e.g., an exhaust input) and/or one or more output port(s) (e.g., an exhaust output). The humid gas (e.g., vapor and/or mist) can migrate into the coalescer from the second zone (headspace) through the one or more input port(s) (e.g., through the pathway such as tubing associated therewith), continue

through the fluidic pathway(s) of the coalescer(s), and out through the one or more output port(s) (e.g., through the pathway such as tubing associated therewith) which may be arranged at various positions therein (e.g., to the exterior through an exhaust vent). As the humid gas migrates through the fluid pathway(s) of the coalescer, fluid can condense on the walls thereof (e.g., in embodiments wherein the temperature therein is lower than in the second zone), and in some embodiments then passively return to the DC (i.e., second zone) and into the reaction mixture. In some embodiments, fluid that has not condensed but only coalesced (or collected) within the coalescer can also passively return to the second zone (HS) and/or the first zone (e.g., being deposited into the reaction mixture).

[0040] In some embodiments, the coalescer may be arranged as a serpentine channel or multiple sets of substantially straight or straight main channels connected to one another through a connecting channel. Units of serpentine channels (e.g., at least one straight main channel or any two or more straight main channels connected by a connecting channel (e.g., **1** in **Fig. 6**), may be physically connected to one another but also may or may not allow fluid and/or gas to pass between such units. In some embodiments, one or more of said main channels are connected to one or more intake ports from the second zone (headspace) (e.g., connected by tubing at a main channel; e.g., **2** in **Fig. 6**). An exit / exhaust port through which non-coalesced fluid may pass to the exhaust system (e.g., comprising the one or more filters (e.g., **4** in **Fig. 6**) is also positioned within said main channels, and is used to connect the same to the filter(s) via a suitable pathway (e.g., tubing (e.g., **3** in **Fig. 6**)). In some embodiments in which the coalescer is positioned horizontally or substantially horizontally on the reactor (e.g., upon the headspace, or insulation surrounding the headspace), the intake port is positioned closest to the second zone (headspace) (e.g., at the bottom of the main channel) and the exit port is positioned distal from the second zone (headspace) relative to the intake port (e.g., at the top of the main channel). Thus, the fluid moves from the second zone (headspace), through a connector (e.g., tubing) and into the coalescer where non-coalesced fluid migrates through the main channels (e.g., in some embodiments through one or more connector channels as well) to the exit port and

through a connector (e.g., tubing) connected to the exhaust system (e.g., a filter), and then exists the system into the atmosphere.

[0041] In some embodiments, multiple coalescers can be included in the system (as in, e.g., **Fig. 1D**). Such multiple coalescers may be connected to one another by one or more fluid channels (e.g., tubing) through, for example, the one or more input and output ports. In such embodiments, each coalescer may be connected to the DC individually and/or through one or another coalescer. Where multiple coalescers are included, only one, more than one, or all of the coalescers may be in contact with the jacketed tank head.

[0042] As mentioned above, one or more filters may be included in the system. The filter is of a type typically used in disposable reactor systems such as, but not necessarily, a sterile filter such as e.g., a 0.2 micron filter. The filter is typically connected (e.g., using tubing) to the HS and/or, more typically, the coalescer. To improve the function of the filter, one or more heating elements may also be associated therewith (e.g., contacting the external surface of the filter) and may serve to dehumidify saturated gas that has exited the coalescer. As discussed below, the exhaust system may include a vacuum pump for pulling air and/or gas from within the system to the exhaust system which may even further improve the useful life of the filter. Thus, the use of heat and/or a vacuum decreases the likelihood of fluid accumulating within, and thereby increasing the functionality of, the filter. Accordingly, one or more filters may be used in the systems described herein.

[0043] The system also typically includes an exhaust system. The exhaust system may comprise an exhaust pump such as a vacuum. In some embodiments, tubing may connects the exhaust pump downstream of a sterile barrier filter attached to the reaction container (e.g., DC); tubing connects the exhaust pump to the coalescer and an inlet or an outlet of a sterile barrier filter attached to the reaction container (e.g., DC); the exhaust pump comprises variable speed control and being optionally operably linked to instrumentation for maintaining reaction container (e.g., DC) pressure; a first fan,

optionally located on the coalescer, draws exhaust gas from the headspace through the coalescing device and into or through a downstream sterile barrier; and/or, the system comprises at least a second fan recirculating exhaust gas within the condenser headspace and / or coalescing device. Each of such exhaust systems provides for the removal of air and/or gas (dry or moist) from the reaction container system. Exemplary exhaust pumps and exhaust systems may include but are not limited to those described in, for instance, US Pat. Pub. No. 2011/0207170 A1 (Niazi, et al.).

[0044] The systems described herein may also include one or more manual and/or automated control systems (e.g., not requiring continuous direct human intervention), including but not limited to one or more remotely controlled control systems. For instance, a control system may continuously monitor one or more conditions occurring within the first and/or second zones (e.g., temperature) and adjust the same to maintain a particular value (e.g., a closed loop system). Using temperature as an exemplary condition, the control system can separately monitor the temperature of the first zone, the second zone (headspace), and/or coalescer (e.g., by being connected to thermostats in each that independently report temperatures to the control system) to optimize the temperature of the reaction components in each area of the system. The temperature may be optimized by, for example, increasing or decreasing the temperature in these areas by modifying the type, temperature, and/or speed of the heat transfer fluid moving through the heat transfer system. Such a control system may be used to maintain the temperature of the first zone at, for instance about 37°C and the temperature of the second zone (headspace) at a temperature of about 32°C. Such control systems typically comprise one or more general purpose computers including software for processing such information and manually or automatically adjusting the desired parameters of the reaction as required by a particular process. As such, the control system may control valves and the like controlling the flow of heat transfer materials to and from the system (e.g., the one or more heat transfer systems thereof).

[0045] An exemplary embodiment of a DC system described herein is illustrated in **Fig. 1**. **Fig. 1A** provides a front view of an exemplary DC system **1** including reaction vessel

2 (typically including door **2a**) comprising within it disposable reaction container **3**, first zone **4**, second zone **5** (i.e., the headspace ("HS")), jacketed tank head **6** (illustrated in more detail in **Fig. 1B**, and which could be a third zone where a third heat transfer system is used here (e.g. "Zone 3" in **Fig. 2**)), filter **7**, exhaust pump **8**, air input (e.g., sparge) **9**, heat exchange apparatus(es) **10** (e.g., heat exchange jacket surrounding second zone **5**) and/or **11** (e.g., heat exchange baffle(s) **11** being positioned in first zone **4**, such baffle(s) optionally extending into and/or also being positioned (e.g., as separate baffles with a heat transfer function independent from those in zone **4**) in second zone **5**), coalescer **13** contacting jacketed tank head **6**, exhaust input **14**, exhaust output **15**, coalesced liquid **16**, DC loading support assembly **17**, and a drive system **18** (e.g., comprising impellers). Optional port belts (**12**) may also be included and positioned as needed and/or desired (e.g., as shown in **Fig. 1A**). Typically, non-aerated liquid is present in first zone **4** and aerated liquid is present in second zone **5** (HS) along with humid gas, although some non-aerated liquid may be present in second zone **5** (HS) (e.g., where the top level of the reaction mixture extends into zone **5** (HS)). The reactor vessel may also comprise a door through which the DC and/or other components of the system may be inserted and removed therefrom (**2a**, and see **Fig. 2**). The top view provided in **Fig. 1B** further illustrates jacketed tank head **6**, coalescer **13** contacting (e.g., on) jacketed tank head **6** and comprising exhaust inputs **14**, exhaust outputs **15**, coalesced liquid **16**, and DC loading support assembly **17**. **Fig. 1C** provides a side view of this exemplary embodiment. As shown therein, in this embodiment, coalescer **13** covers approximately 75% of the top of second zone **5** (HS) and is contacting and/or positioned on jacketed tank head **6**. DC **3** is positioned within reaction vessel **2** and provides a space (the first zone **4**) within which a reaction takes place (e.g., a fermentation) and a headspace (the second zone **5**).

[0046] **Figs. 1D-F** provide additional views of these and other embodiments. **Fig. 1D** provides a view of an embodiment in which multiple coalescers are positioned on the jacketed tank head. **Fig. 1E** provides a top-down view of the jacketed tank head covering approximately 75% of the top surface of the DC where, in this embodiment, the seam in the DC is covered by the jacketed tank head, thereby providing additional

physical support thereto. **Fig. 1F** illustrates a side view of the DC in which the first zone ("Zone 1") is maintained at 35–40°C and the second zone (HS) is maintained at a cooler temperature (designated "Max Cool" in this illustration).

[0047] As discussed above, and with reference to **Fig. 1**, disposable reaction container **3** comprises first zone **4** in which a reaction is carried out and second zone **5** providing a headspace (HS). First zone **4** therefore typically comprises a fluid reaction mixture (e.g., the components and products of a biological reaction) which may be agitated (e.g., stirred) by drive system **18** (e.g., comprising impellers). Air (e.g., gas) is typically introduced into first zone **4** and migrates into and/or through the reaction mixture. Second zone **5** (HS) typically extends from the top fluid level of the reaction mixture and the top of DC **3** (which typically extends to the top of reaction vessel **2** and/or and/or is physically supported by jacketed tank head **6**). The first and second zones may also be associated with (e.g., in contact with) one or more heat exchange apparatus(es) **10** and **11** that may be the same or different in each zone. The heat exchange apparatus(es) may individually or together (e.g., when included a single unit transversing first zone **4** and second zone **5** (HS)) serve to maintain the average temperature of the reaction mixture contained within disposable reaction container **3**, and more specifically first zone **4** and/or second zone **5** (HS). The heat exchange apparatus(es) are typically arranged to maintain a desired temperature in first zone **4** and a lower (i.e., cooler) temperature in second zone **5** (HS) in order to induce condensation in the HS. For instance, a heat exchange apparatus may maintain the temperature of first zone **4** at 35–40°C and the temperature of second zone **5** (HS) at a temperature of, for instance 30°C. The heat transfer fluid of a single heat transfer apparatus extending between first zone **4** and second zone **5** may maintain the different temperatures of these zones since the temperature of the reaction mixture is typically higher than the temperature of the headspace. The cooling effect provided by the heat exchange apparatus can therefore be relative to the temperature of the contents of each zone (e.g., the reaction mixture within first zone **4** and the air and the like within second zone **5** (HS)). For instance, the temperature of a reaction mixture in first zone **4** may be lowered from 50°C to 40°C by the heat exchange apparatus, while the temperature within second zone **5** may be

lowered from 35°C to 30°C by the same heat exchange apparatus. As mentioned above, in some embodiments, different heat exchange apparatuses may be provided to each of first zone **4** and second zone **5**, and each of such apparatuses may separately cool their respective zones.

[0048] As described above, the heat exchange system may comprise a jacketed system (**10**) surrounding disposable reaction container **3**, and/or one or more baffle systems (**11**). The jacketed system may be incorporated into the vessel as part of a vessel wall, for example. Jacketed tank head **6**, positioned at the top end of the reaction vessel, may be jacketed as described herein (e.g., using a dimpled sandwich arrangement) and typically covers at least 5% of the top surface of second zone **5** (HS). In some embodiments, jacketed tank head **6** may cover more than 5% of the top surface of second zone **5** (HS), such as about any of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, or 90% of that surface. Associated with or positioned upon, or adjacent to or on, jacketed tank head **6** in the embodiment illustrated by **Fig. 1**, is coalescer **13**. As mentioned above, at least one surface of the coalescer typically contacts jacketed tank head over part (e.g., at least about 25%) of the surface area of that coalescer surface. Coalescer **13** comprises exhaust input(s) **14** connected to second zone **5** (HS) through which gas moves from second zone **5** into coalescer **13**, and exhaust output(s) **15** through which gas (e.g., humidified gas) may leave coalescer **13** and enter the exhaust system for discharge from the system (e.g., into the environment). Exhaust output **15** is typically also connected to filter **7**, which is connected to exhaust system **8**. Coalesced liquid **16** typically leaves second zone **5** (HS) and collects in coalescer **13**. Coalesced liquid **16** may or may not leave coalescer **13** but is typically not actively removed therefrom. As such, coalesced liquid **16** may leave coalescer **13**, e.g., passively (e.g., by gravity) returning to second zone **5** (HS) and then, typically first zone **4**. This movement is illustrated in **Fig. 1A** by the upward and downward pointing arrows positioned between second zone **5** and coalescer **13**. In this embodiment, the various parts of the system including but not limited to second zone **5** (HS), coalescer **13**, filter **7** and exhaust system **8** are connected using flexible tubing.

[0049] **Figs. 2A-E** illustrate various views of an exemplary reactor vessel in which a DC may be maintained. As shown in **Fig. 2A**, for instance, the reactor vessel may comprise and agitator assembly, a door secured by hinge and latch assemblies, a top head with heat transfer capabilities (i.e., a dimpled jacket structure provided by “Jacketed Tank Head (with inflated heat transfer surface (H.T.S.)) (Zone 3)”), and DC loading support assembly. **Fig. 2B** provides another view of the reactor vessel, showing dimpled heat transfer surfaces associated with the first and second zones (e.g., “Dimpled Jacket (Zone 1)” providing heat transfer to first zone **4**; and “Dimpled Jacket (Zone 2)” and Jacketed Tank Head (“Zone 3”) providing heat transfer to the second zone **5** (HS), these heat transfer systems being contiguous or not contiguous with one another). **Fig. 2C** provides top view of this exemplary reactor vessel and another view of the jacketed tank head (“Jacketed Tank Head (Zone 3)”) **Fig. 2D** illustrates a view of the reactor opposite that of **Fig. 2A** (i.e., the door is on the opposite side of the reactor vessel shown in this view), and also shows dimpled heat transfer surfaces associated with zones 1 and 2 (“Dimpled H.T.S. (Zone 1)” and “Dimpled H.T.S. (Zone 2)”, respectively), as well as “Jacketed Tank Head (Zone 3)” also providing heat transfer to the second zone **5** (HS)). **Fig. 2D** also shows a “4” Gap” between the heat transfer surfaces of the first and second zones. It should be understood that the length of this gap may vary, and 4” is only referred to here as a non-limiting example. **Fig. 2E** also shows the “Jacketed Tank Head (Zone 3)”, similar to **Fig. 2C**. It should be understood that each of these illustrations are only exemplary, and variations may be made thereto.

[0050] **Fig. 3** illustrates an alternate or additive arrangement of the system in which a coalescing device comprising a coalescer (**19**) is at least partially contacting and/or constrained by one or more heat transfer surfaces (e.g., one or more dimple jacket-type heat transfer units such as **20A** and **20B**) other than or in addition to the jacketed tank head is connected thereto. In such embodiments, one or more heat transfer surfaces chilled by a heat transfer fluid (e.g., water), such as one or more plates (preferably two positioned on either side of the coalescer) that contact the coalescer or come into contact with the coalescer as it expands as result of the entry of fluid (coalesce (“C”)) and humidified gas into the coalescer (e.g., where the coalescer is constructed of a

flexible material surrounding an interior chamber, including as tubing alone and/or contained within an interior chamber) through the gas intake thereof ("I"), and cool the interior chamber and its contents. In these embodiments, as in others described herein, the coalescer provides a tortuous and/or serpentine fluid pathway through which the coalesce and/or humid gas may migrate. The fluid pathway may also comprise one or more types of mesh and/or solids (like the anti-foam device described above) throughout all or part thereof. The surface area of the coalescer in these embodiments is typically not in contact with the heat transfer surfaces over its entire surface area. For instance, in some embodiments, the coalescer contacts the one or more heat transfer surfaces over 50% or less of its surface area (see, e.g., the example illustrated in **Fig. 3**). As in other embodiments, the contents of the coalescer may also be cooled by the ambient temperature of the environment surrounding the coalescer that are not in contact with the active heat transfer system (e.g., the one or more plates), the ambient temperature typically being about room temperature (e.g., 25°C). The contents of the interior chamber are typically humidified gas and liquid migrating from the headspace (e.g., zone **5**). Expansion of the coalescer promotes drainage of coalesced liquid back into the DC, either by passive forces (e.g., gravity) or actively (e.g., using a pump). Humidified gas continues its migration through the system, moving through the coalescer and out the exhaust thereof ("O"), then the filter (which may be heated to dehumidify the humidified gas), and into the environment through an exhaust outlet. Such movement may be assisted through the use of an exhaust system as described above which may comprise, e.g., one or more fans.

[0051] This disclosure provides and describes system(s) (e.g., reaction systems) comprising a reaction container (e.g., a DC); at least one heat transfer system; a jacketed tank head positioned above the reaction container (e.g., a DC); and, one or more coalescers comprising an internal tortuous fluidic pathway and contacting (e.g., typically being positioned on) the jacketed tank head; wherein: the disposable reaction container can comprise a first zone that can comprise a reaction mixture maintained at a first temperature; the disposable reaction container can comprise a second zone comprising a headspace above the reaction mixture into which humid gas migrating from

the reaction mixture can migrate; the second zone can be maintained at a second temperature lower than that of the first temperature; and, fluid migrating from the second zone may coalesce within the internal tortuous fluidic pathway of the coalescer. In some embodiments, then, the system includes: at least one disposable reaction container comprising first and second zones, the first zone comprising a reaction mixture and the second zone comprising a headspace into which humid gas migrates from the first zone; at least one heat transfer system for maintaining the first zone at a first temperature; at least one heat transfer system for maintaining the second zone at a second temperature lower than the first temperature; and, fluid migrates from the headspace (i.e., the second zone) coalesces within the internal fluidic pathway of the coalescer. In some embodiments, the system comprises a reaction vessel comprising a heat transfer system. In some embodiments, the jacketed tank head is integral with the reaction vessel. In some embodiments, the reaction vessel also comprises one or more heat transfer baffles. In some embodiments, the jacketed tank head physically supports a disposable reaction container. In some embodiments, heat transfer is accomplished by radiative, convective, conductive or direct contact, and/or the heat transfer fluid is gas and/or liquid. In some embodiments, a first heat transfer system is associated with the first zone and a second heat transfer system is associated with the second zone. In some embodiments, a third heat transfer system is also provided by the jacketed tank head, and may be in fluidic communication with the first and/or second heat transfer systems. In some embodiments, at least two of the heat transfer systems are contiguous with one another (e.g., interconnected by a fluidic pathway), at least one of the heat transfer systems is not contiguous with at least one other heat transfer system. In some embodiments, the second and third heat transfer systems are interconnected. In some embodiments, the same type of heat transfer fluid is in each of the one or more of the heat transfer systems, while in some embodiments, the heat transfer fluid in each of the one or more heat transfer systems is different. In preferred embodiments, the second zone is positioned above the first zone, "above" being relative to the direction of flow of the humid gas from the reaction mixture in the first zone into the second zone (e.g., the second zone is physically above the first zone). In some embodiments, the second zone is partially defined by an upper exterior surface adjacent to the jacketed

tank head. As mentioned above, this arrangement allows the disposable reaction container to withstand higher pressures than would otherwise be possible. In some embodiments, the or at least one of the coalescers comprises upper and lower surfaces and the internal tortuous fluidic pathway is contiguous with either of both of said upper and/or lower surfaces. In some embodiments, the or at least one of the coalescers is comprised of at least two pieces of flexible material fused together to form a chamber comprising the internal tortuous fluidic pathway. In some embodiments, the internal tortuous fluidic pathway of the can be defined by fused sections of the at least two pieces of flexible material. In some embodiments, the internal tortuous fluidic pathway is defined by a third material contained within the chamber. In some embodiments, at least one anti-foam device positioned between the disposable reaction container and the or at least one of the coalescers. In some embodiments, the system may comprise, typically configured as part of the reactor vessel, at least one baffle comprising a first sub-assembly consisting essentially of a first material adjoined to a second material to form a first distribution channel; a second sub-assembly consisting essentially of a first material adjoined to a second material to form a second distribution channel; optionally a closure bar that adjoins the first assembly and the second sub-assembly to one another; and, a relief channel between the first sub-assembly and the second sub-assembly; wherein the closure bar, when present, sets the width of the relief channel, and, the distribution channels and the relief channel do not communicate unless a leak forms within a distribution channel. In some embodiments, at least one such baffle is associated with the first zone and a separate such baffle is associated with the second zone. As mentioned above, in some embodiments, the system may comprise multiple coalescers that may or may not be interconnected through one or more fluidic pathways and/or at least one anti-foam device. In some embodiments, at least one or each coalescer comprises a lower surface and that at least about 25% of the surface area of said lower surface is on the jacketed tank head. In some embodiments, the coalescer can comprise a flexible container comprising a tortuous fluid pathway; a flexible, semi-rigid, or rigid tubular form providing for cyclonic removal of gas from the headspace; and/or, a container comprising mesh and/or packed solids. Typically, the systems described here comprise an exhaust pump. In some such embodiments, tubing can

connect the exhaust pump downstream of a sterile barrier filter in fluidic communication with the disposable reaction container; tubing can connect the exhaust pump to the coalescer and an inlet or an outlet of a sterile barrier in fluidic communication with the disposable reaction container; the exhaust pump can include variable speed control and/or can optionally be operably linked to instrumentation for maintaining DC pressure; the exhaust system can include at least a first fan, optionally located on the condenser, that can draw exhaust gas from the headspace through the coalescing device and into and/or through a downstream sterile barrier; and/or, optionally at least one fan recirculating exhaust gas within the condenser headspace and / or coalescing device. In some embodiments, the system comprises a heat transfer system at least partially directly in direct contact with the exterior of the second zone and is at least partially not positioned within the reaction vessel (e.g., as illustrated in **Fig. 5**). Those of ordinary skill in the art will be able to derive additional embodiments from this disclosure.

[0052] In some embodiments, the systems described herein may comprise one or more pressure transmitters or sensors, load cells, and/or scales (e.g., platform scale) in contact with the second zone (e.g., headspace) which measures the pressure upon the walls of the reaction container within the second zone by, e.g., gases and fluids present therein. In some embodiments, the pressure transmitter can be a diaphragm pressure transmitter or load cell(s). The pressure transmitter may include a membrane for detecting pressure on the walls of the reaction container. In some embodiments, the pressure transmitter(s) or load cell(s) contact the exterior surface of the reaction container (e.g., the membrane of a diaphragm pressure transmitter contacts the exterior surface of the reaction container adjacent to the second zone). In some embodiments, the pressure transmitter is in communication with a control system for monitoring (e.g., continuously monitoring) the pressure within the second zone (e.g., by receiving and analyzing information regarding that pressure) and adjusting the same as required to ensure the pressure does not exceed the ability of the reaction container (e.g., the disposable reaction container) to maintain its integrity in the presence of that pressure. In some embodiments, the control system adjusts the pressure within the second zone using an exhaust pump (e.g., by activating the exhaust pump to remove some of the

gases and the like from the second zone). In some embodiments, the control system is automated (e.g., using software). Other embodiments comprising such pressure transmitters are also contemplated herein as will be understood by those of ordinary skill in the art.

[0053] In some embodiments, the reaction system may include a disposable reaction container comprising a wall having exterior and interior surfaces surrounding a reaction chamber, the interior surface being directly adjacent to the reaction chamber; one or more fluidic channels (or pathways) extending into the reaction chamber through the wall; the fluidic channel comprising multiple fluidic exits and terminating in a closed end. As the fluidic channel terminates in a close end, fluid flowing through the fluidic channel exits the same through the fluidic exits. In some embodiments, the fluidic channel may be or comprise tubing comprising fluidic exits (e.g., as holes in the walls of the tubing). In some embodiments, the fluid exits the fluidic channel under sufficient pressure to cause the fluid to contact the interior surface by, e.g., spraying outwards towards the same. In some embodiments, the closed end is formed by, e.g., fused walls of the fluidic channel or a cap covering the end of the fluidic channel. In some embodiments, the fluidic exits are positioned approximately centrally within the reaction chamber relative to the interior surface. In some embodiments, the fluidic exits within the reaction chamber are distributed relatively evenly along the fluidic channel. In some embodiments, the fluidic exits are arranged to distribute fluid from the fluidic channel at various angles; and/or to distribute the fluid away from the fluidic channel in substantially all perpendicular and/or upward directions, and/or substantially all directions. In some embodiments, the reaction chamber is at least partially spherical (e.g., forming a shape such as dome (e.g., resembling the hollow upper half of a sphere)). In some embodiments, the fluid flowing through the fluidic channel is a cleaning solution. In some embodiments, the flow of fluid into the fluidic channel and/or the reaction chamber is regulated by a control system, such as an automated control system (e.g., using software). Exemplary reaction systems for which these embodiments may be suitable include but are not limited to any described herein (e.g., reaction systems comprising first and second zones (e.g., a headspace)), any described in U.S. Pat. No. 8,658,419

B2; U.S. Pat. No. 9,228,165 B2; and/or U.S. Pat. Pub. No. 2016/0272931 A1, each of which being hereby incorporated in their entireties into this disclosure. Other embodiments comprising such fluid channel structures are also contemplated herein as will be understood by those of ordinary skill in the art.

[0054] Acid and base are routinely added to reactor systems (e.g., fermenters, bioreactors, and the like) to adjust pH between pH 2.5 and 11 in order to carry out certain processes such as, e.g., to digest cells, inactivate viruses, or for chemical decontamination of such systems (e.g., from microbes or active agents). In some embodiments, a strong acid or base may need to be used to treat (e.g., clean) the reaction chamber. Typical materials such as polyethylene films and polyolefin ports are understood by those of ordinary skill in the art to be compatible (e.g., structurally stable) with solutions having a pH of from 2.5 to 11, with only limited supporting data as to the pH at which such materials actually fail. There is a need in the art for reactor systems suitable for use with solutions having a pH of from zero to 14. In some embodiments, then, the above described one or more fluidic channels and related structures (e.g., ports) are chemically compatible (e.g., structurally stable) with solutions having a pH of from zero to 14 (referred to herein as “low/high pH compatibility”). Exemplary materials that can provide such low/high pH compatibility include a thermoplastic elastomer (TPE) such as, for instance, a mixture comprising a thermoplastic elastomer (e.g., at least about 20% wt %) and polyolefin (less than about 50% wt), optionally further comprising styrene, and/or as described in U.S. Pat. No. 9,334,984 B2 (Siddhamalli, et al.) An exemplary low/high pH compatible tubing that can be used as described herein is the commercially available C-Flex® tubing (Saint-Gobain Performance Plastics Corp., e.g., comprising any of formulations 374, 082, or 072). In some embodiments, the acid or base solution may be maintained in a low/high pH-compatible container (e.g., a glass container) and delivered to the reaction chamber through a high/low pH compatible fluidic channel (e.g., tubing comprised of a TPE). The low/high pH compatible fluidic channel can extend through a port comprised of a low/high pH-incompatible material (e.g., a polyolefin port) leading from the exterior to the interior of the reaction chamber, or it can be flush with the end of the port opening into the reaction chamber such that the

low/high pH-incompatible material comprising the port (e.g., a polyolefin) is not contacted by the high/low pH solution. In some embodiments, the polyolefin port can include a disc-shaped surface having a diameter wider than that of the fluidic channel (see, e.g., **Fig. 4**). **Fig. 4** illustrates exemplary arrangements of a low/high pH-compatible fluidic channel (e.g., tube) (1) within a larger diameter tube that is typically comprises of a material that is not low/high pH-compatible (i.e., a material that is low/high pH-incompatible) (2). In **Fig. 4**, the low/high pH-compatible tube (1) and the low/high pH-incompatible tubing (2) is shown with a port structure (3 including port disc 4a and port neck 4b). In some embodiments, the port may comprise a port disc (4a) an extended neck (5) that effectively serves as the outside tube (that with a diameter larger than the low/high pH-compatible fluidic channel/tube). The low/high pH-compatible tube (1) is typically connected to a source of the low or high pH solution that is to be deposited into the reaction chamber through the low/high pH-compatible tube (1). Using this arrangement, the high/low pH solution can then be deposited into the reaction chamber and any fluid contained therein (e.g., reactants left over after reaction is complete) without contacting and/or damaging the pH-incompatible parts of the reactor system. Fluid contained within the reaction chamber (including that after addition of the low or high pH solution) is maintained at a pH compatible with the material of which the disposable container is comprised (e.g., the material surrounding or forming the reaction chamber). Such a compatible pH is typically from about 2.5 to about 11 (e.g., an acceptable set/control point). These modifications to the systems described herein allow for the passage of low/high pH solutions (i.e., below pH 2.5 or above pH 11) from a source container to the reaction chamber without the risk of material failure due to pH-incompatibility. Thus, in some embodiments, the disposable reaction systems described herein can include a fluidic channel, and optionally some or preferably all tubing leading to the fluidic channel and/or reaction chamber, comprised of a material that remains structurally intact in the presence of a fluid having a pH of between zero and 14. In some embodiments, the material is or comprises a thermoplastic elastomer. Other arrangement of such parts, and similar parts, and other low/high pH-compatible materials, are also contemplated herein as would be understood by those of ordinary skill in the art.

[0055] One or more low/high pH-compatible tubes (e.g., fluidic channels) may be prepared and included in tubing sets for use in the low/high pH solution delivery system (e.g., “tube-sets”, “tube-within-a-tube” system; see, e.g., the exemplary embodiments illustrated in **Fig. 4**). For example, a first fluidic channel (e.g., tube) comprised on a low/high pH-compatible material (e.g., a material is stable in a pH range of from 0-14) may be inserted into or constructed within (e.g., over-molding) second fluidic channel (e.g., tube) that is not comprised of a low/high pH-compatible material (e.g., a material is not stable in a pH range of from 0-14). In some embodiments, such tube-sets may be constructed by, for example: constructing an over-molded part (over-molding the inner diameter (ID) of an outer tube to the outer diameter (OD) of an inner tube), and inserting the inner tube through the port (leading to the reaction chamber) where the outer hose is positioned over the inner hose and the barb (where present). In some embodiments, such tube-sets may be constructed by, for example constructing an over-molded part, inserting an inner tube (e.g., hose) through the port comprised of a low/high pH-incompatible material such that the outer tubing (e.g., hose) is positioned over the inner tube (e.g., hose) and over the barb, filling the annular space with resin and melting the same to achieve flow/sealing of the two tubes (e.g., thereby filling the annular space). Other methods for manufacturing such pH-compatibility systems are also contemplated herein as would be understood by those of ordinary skill in the art.

[0056] Thus, in some embodiments, this disclosure provides systems comprising a reaction container; optionally but preferably at least one heat transfer system; optionally a jacketed tank head positioned above the reaction container; optionally but preferably a coalescer comprising an internal tortuous fluidic pathway; at least one exhaust filter; and, a heated air source; wherein: the reaction container can comprise a first zone comprising a reaction mixture maintained at a first temperature; the reaction container can comprise a second zone comprising a headspace above the reaction mixture into which humid gas migrating from the reaction mixture can migrate; the second zone can be maintained at a second temperature lower than that of the first temperature; fluid migrating from the second zone may coalesce within the internal tortuous fluidic pathway

of the coalescer, when present; and, exhaust gas exits the reaction container and then exits the system through the exhaust filter; the heated air source introduces heated air into the exhaust gas to produce a mixed exhaust gas after it exits the reaction container and prior to or concurrent with its exit of the system through the exhaust filter. In some embodiments of such systems, the heated air source introduces air into the exhaust gas after it exits the reaction container and prior to its exit of the system through the exhaust filter. In some embodiments, the system comprises a coalescer through which the exhaust gas traverses, and the heated air source introduces air into the exhaust gas after it exits the coalescer to produce the mixed exhaust gas, which then exits the system through the exhaust filter. In preferred embodiments, the relative humidity of the mixed exhaust gas is less than that of the exhaust gas. In some embodiments: a) the reaction container is a disposable reaction container; b) the system further comprises a reaction vessel comprising a heat transfer system; c) the system comprises a jacketed tank head integral with a reaction vessel in which the reaction system is contained; d) the system comprises a coalescer; the disposable reaction container comprises first and second zones, the first zone comprising a reaction mixture and the second zone comprising a headspace into which humid gas migrates from the first zone; the first zone is maintained at a first temperature; the second zone at a second temperature lower than the first temperature; and, fluid migrating from the headspace coalesces within the internal fluidic channel of the coalescer; e) heat transfer is accomplished by radiative, convective, conductive or direct contact, and/or the heat transfer fluid is gas and/or liquid; f) the disposable reaction container comprises first and second zones, the first zone comprising a reaction mixture and the second zone comprising a headspace into which humid gas migrates from the first zone, and a first heat transfer system associated with the first zone and a second heat transfer system associated with the second zone; g) the system comprises a jacketed tank head; and the disposable reaction container comprises first and second zones, a first heat transfer system associated with the first zone, a second heat transfer system associated with the second zone, and a third heat transfer system is provided by the jacketed tank head that is optionally in fluidic communication with the first and/or second heat transfer systems, at least two of the heat transfer systems are contiguous with one another, at least one of the heat transfer

systems is not contiguous with at least one other heat transfer system, at least two of the heat transfer systems are interconnected by a fluidic pathway, the second and third heat transfer system are interconnected, and/or the same type of heat transfer fluid is in each heat transfer system; h) the second zone is positioned above the first zone; i) the system comprises a jacketed tank head and the second zone is partially defined by an upper exterior surface adjacent to the jacketed tank head; j) the system comprises a coalescer wherein: the coalescer comprises upper and lower surfaces and the internal tortuous fluidic pathway is contiguous with the either of both of said upper and/or lower surfaces, the coalescer is comprised of at least two pieces of flexible material fused together to form a chamber comprising the internal tortuous fluidic pathway, the internal tortuous fluidic pathway is defined by fused sections of the at least two pieces of flexible material, and/or the internal tortuous fluidic pathway is defined by a third material contained within the chamber; k) the system comprises a coalescer further comprises at least one anti-foam device positioned between the disposable reaction container and the coalescer; l) the system comprises a heat transfer system comprising at least one baffle comprising a first sub-assembly consisting essentially of a first material adjoined to a second material to form a first distribution channel; a second sub-assembly consisting essentially of a first material adjoined to a second material to form a second distribution channel; optionally a closure bar that adjoins the first assembly and the second sub-assembly to one another; and, a relief channel between the first sub-assembly and the second sub-assembly; wherein the closure bar, when present, sets the width of the relief channel, and, the distribution channels and the relief channel do not communicate unless a leak forms within a distribution channel, optionally wherein at least one such baffle is associated with the first zone and a separate such baffle is associated with the second zone; m) the system comprises multiple coalescers, optionally wherein the coalescers are not interconnected through one or more fluidic pathways, are interconnected through one or more fluidic pathways, one or more of the coalescers is associated with at least one anti-foam device, each coalescer comprises a lower surface in contact with the jacketed tank head; n) the system comprises a coalescer that comprises a flexible container comprising a tortuous fluid pathway, comprises a flexible, semi-rigid, or rigid tubular form providing for cyclonic removal of gas from the

headspace; and/or, comprises a container comprising mesh and/or packed solids; o) the system comprises an exhaust pump, optionally wherein: tubing connects the exhaust pump downstream of a sterile barrier filter in fluidic communication with the disposable reaction container; tubing connects the exhaust pump to the coalescer and an inlet or an outlet of a sterile barrier in fluidic communication with the disposable reaction container; the exhaust pump comprises variable speed control and being optionally operably linked to instrumentation for maintaining DC pressure; a first fan, optionally located on the condenser, draws exhaust gas from the headspace through the coalescing device and into or through a downstream sterile barrier; and/or, at least a second fan recirculating exhaust gas within the condenser headspace and / or coalescing device; p) the system comprises a jacketed tank head that physically supports a disposable reaction container; q) the system comprises a heat transfer system at least partially directly in direct contact with the exterior of the second zone and at least partially not positioned within the reaction vessel; and/or, r) the reaction container comprises a first zone comprising a reaction mixture maintained at a first temperature; a second zone comprising a headspace above the reaction mixture into which humid gas migrating from the reaction mixture can migrate; and at least one diaphragm pressure transmitter, load cell, and/or scale in contact with the second zone, optionally comprising a membrane for detecting pressure in contact with the reaction container, detects the pressure exerted upon the reaction container by gases and fluids present in the second zone, and/or contacts the exterior surface of the reaction container is in communication with a control system for adjusting the pressure within the second zone in response to information received from diaphragm pressure transmitter, optionally wherein the control system continuously monitors information generated by the system, adjusts the pressure within the second zone using an exhaust pump, and/or is automated. In preferred embodiments, the reaction container included in such systems is a disposable reaction container. In some preferred embodiments, the system comprises: a) at least one exhaust line leading from a disposable reaction container (DC) through which exhaust gas exiting the DC traverses; b) an exhaust filter through which the exhaust gas traverses to exit the system; c) at least one source of external heated air; d) at least one fluidic pathway connecting the at least one source of external heated air to the at least one exhaust line;

and, e) optionally a sterile filter between the at least one source of external heated air to the at least one exhaust line, and at least one second fluidic pathway connecting heated air that exits the sterile filter and the at least one exhaust line. In preferred embodiments, the external heated air comprises a temperature sufficiently above that of the exhaust gas such that upon mixture of the external heated air and the exhaust gas to produce a mixed exhaust gas, the relative humidity of the mixed exhaust gas is less than that of the exhaust gas. In preferred embodiments, the relative humidity of the mixed exhaust gas is sufficiently low such that moisture from the mixed exhaust gas does not accumulate on the filter as the mixed exhaust gas exits the system. In preferred embodiments, this disclosure also provides methods for decreasing the relative humidity of an exhaust gas within a reaction system comprising traversing the exhaust gas through any such system. In preferred embodiments, this disclosure also provides methods for carrying out a reaction using any such system. Other aspects and embodiments of this disclosure are also contemplated as will be understood by those of ordinary skill in the art.

[0057] The terms “about”, “approximately”, and the like, when preceding a list of numerical values or range, refer to each individual value in the list or range independently as if each individual value in the list or range was immediately preceded by that term. The terms mean that the values to which the same refer are exactly, close to, or similar thereto. The term “maintain” with respect to temperatures is not meant to indicate that a particular temperature remains the same over any particular time period. It should be understood that a temperature “maintained” at a particular level will vary over time by, for example 0.1-10%, such as about any of 1%, 5%, or 10%. “Fixably attached”, “affixed”, or “adjoined” means that at least two materials are bonded to one another in a substantially permanent manner. The various parts described herein may be bonded to one another using, for example, welding, using an adhesive, another similar process, and/or using connectors such as tubing. The parts must remain attached to one another during use, meaning that the points of attachment (e.g., boundaries, joints) between the parts must be able to withstand the hydraulic and other forces encountered within the reaction vessel and between the parts due to, e.g.,

the motion of the reactor contents in response to the action of the agitator mechanism in addition to the pressures created from the heat transfer media flow. “Optional” or “optionally” means that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where the event or circumstance occurs and instances where it does not. Ranges may be expressed herein as from about one particular value, and/or to about another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent about or approximately, it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint. Ranges (e.g., 90-100%) are meant to include the range *per se* as well as each independent value within the range as if each value was individually listed. The term “on” and “upon”, unless otherwise indicated, means “directly on or directly connected to the other element” (e.g., two parts of the systems described herein). The term “adjacent to” may refer to an indirect connection between two elements such as parts of the systems described herein.

[0058] A “fluidic pathway” is a pathway within the systems described herein (e.g., a channel) through which one or more fluids (e.g., a gas or liquid) can migrate and/or can be transported and / or moved through. A “fluidic connection” or to be “in fluidic communication” refers to at least two parts of the systems described herein through which fluid may directly and/or indirectly flow (e.g., as a fluid may move from a disposable reaction container into a coalescer, and/or *vice-versa*, thus the disposable reaction container and coalescer share a “fluidic connection” and are in “fluidic communication” with one another). A “fluid pathway” or “fluidic pathway” or “fluidic channel” is a pathway as commonly understood by those of ordinary skill in the art (e.g., a channel) through which fluid may flow. Other similar terms in this disclosure will be understood by those of ordinary skill in the art when read in its proper context.

[0059] All references cited within this disclosure are hereby incorporated by reference

in their entirety. Certain embodiments have been described herein, but are provided as examples only and are not intended to limit the scope of the claims in any way. While certain embodiments have been described in terms of the preferred embodiments, it is understood that variations and modifications will occur to those skilled in the art. Therefore, it is intended that the appended claims cover all such equivalent variations that come within the scope of the following claims.

Claims

What is claimed is:

1. A system comprising:
 - a. a disposable reaction container;
 - b. at least one heat transfer system;
 - c. a jacketed tank head positioned above the disposable reaction container;
 - d. a coalescer comprising an internal tortuous fluidic pathway and exhaust gas;
 - e. an exhaust line leading from the coalescer to at least one exhaust filter; and,
 - f. a heated air source that introduces heated air from a heated air source through a fluidic pathway into the exhaust gas to produce a mixed exhaust gas having a relative humidity of the less than that of the exhaust gas;

wherein:

the reaction container can comprise a first zone comprising a reaction mixture maintained at a first temperature;

the reaction container can comprise a second zone comprising a headspace above the reaction mixture into which humid gas migrating from the reaction mixture can migrate;

the second zone can be maintained at a second temperature lower than that of the first temperature;

fluid migrating from the second zone coalesces within the internal tortuous fluidic pathway of the coalescer;

the mixed exhaust gas is produced in a fluidic pathway leading to the at least one exhaust filter or within a container that contains the at least one exhaust filter; and,

the mixed exhaust gas exits the system through the at least one exhaust filter.

2. The system of claim 1 wherein the heated air source introduces air into the exhaust gas after it exits the reaction container and prior to its exit of the system through the at least one exhaust filter.
3. The system of claim 1 or 2 wherein the system comprises the coalescer through which the exhaust gas traverses, and the heated air source introduces air into the exhaust gas after it exits the coalescer to produce the mixed exhaust gas, which then exits the

system through the at least one exhaust filter.

4. The system of claim 1 wherein:

- a) the system further comprises a reaction vessel comprising a heat transfer system;
- b) the system comprises a jacketed tank head integral with a reaction vessel in which the reaction system is contained;
- c) the system comprises a coalescer; the disposable reaction container comprises first and second zones, the first zone comprising a reaction mixture and the second zone comprising a headspace into which humid gas migrates from the first zone; the first zone is maintained at a first temperature; the second zone at a second temperature lower than the first temperature; and, fluid migrating from the headspace coalesces within the internal fluidic channel of the coalescer;
- d) heat transfer is accomplished by radiative, convective, conductive or direct contact, and/or the heat transfer fluid is gas and/or liquid;
- e) the disposable reaction container comprises first and second zones, the first zone comprising a reaction mixture and the second zone comprising a headspace into which humid gas migrates from the first zone, and a first heat transfer system associated with the first zone and a second heat transfer system associated with the second zone;
- f) the system comprises a jacketed tank head; and the disposable reaction container comprises first and second zones, a first heat transfer system associated with the first zone, a second heat transfer system associated with the second zone, and a third heat transfer system is provided by the jacketed tank head that is optionally is in fluidic communication with the first and/or second heat transfer systems, at least two of the heat transfer systems are contiguous with one another, at least one of the heat transfer systems is not contiguous with at least one other heat transfer system, at least two of the heat transfer systems are interconnected by a fluidic pathway, the second and third heat transfer system are interconnected, and/or the same type of heat transfer fluid is in each heat transfer system;
- g) the second zone is positioned above the first zone;
- h) the system comprises a jacketed tank head and the second zone is partially defined by an upper exterior surface adjacent to the jacketed tank head;

- i) the system comprises a coalescer wherein: the coalescer comprises upper and lower surfaces and the internal tortuous fluidic pathway is contiguous with the either of both of said upper and/or lower surfaces, the coalescer is comprised of at least two pieces of flexible material fused together to form a chamber comprising the internal tortuous fluidic pathway, the internal tortuous fluidic pathway is defined by fused sections of the at least two pieces of flexible material, and/or the internal tortuous fluidic pathway is defined by a third material contained within the chamber;
- j) the system comprises a coalescer further comprises at least one anti-foam device positioned between the disposable reaction container and the coalescer;
- k) the system comprises a heat transfer system comprising at least one baffle comprising a first sub-assembly consisting essentially of a first material adjoined to a second material to form a first distribution channel; a second sub-assembly consisting essentially of a first material adjoined to a second material to form a second distribution channel; optionally a closure bar that adjoins the first assembly and the second sub-assembly to one another; and, a relief channel between the first sub-assembly and the second sub-assembly; wherein the closure bar, when present, sets the width of the relief channel, and, the distribution channels and the relief channel do not communicate unless a leak forms within a distribution channel, optionally wherein at least one such baffle is associated with the first zone and a separate such baffle is associated with the second zone;
- l) the system comprises multiple coalescers, optionally wherein the coalescers are not interconnected through one or more fluidic pathways, are interconnected through one or more fluidic pathways, one or more of the coalescers is associated with at least one anti-foam device, each coalescer comprises a lower surface in contact with the jacketed tank head;
- m) the system comprises a coalescer that comprises a flexible container comprising a tortuous fluid pathway, comprises a flexible, semi-rigid, or rigid tubular form providing for cyclonic removal of gas from the headspace; and/or, comprises a container comprising mesh and/or packed solids;
- n) the system comprises an exhaust pump, optionally wherein: tubing connects the exhaust pump downstream of a sterile barrier filter in fluidic communication with the disposable reaction container; tubing connects the exhaust pump to the

coalescer and an inlet or an outlet of a sterile barrier in fluidic communication with the disposable reaction container; the exhaust pump comprises variable speed control and being optionally operably linked to instrumentation for maintaining DC pressure; a first fan, optionally located on the condenser, draws exhaust gas from the headspace through the coalescing device and into or through a downstream sterile barrier; and/or, at least a second fan recirculating exhaust gas within the condenser headspace and / or coalescing device;

- o) the system comprises a jacketed tank head that physically supports a disposable reaction container;
- p) the system comprises a heat transfer system at least partially directly in direct contact with the exterior of the second zone and at least partially not positioned within the reaction vessel; and/or,
- q) the reaction container comprises a first zone comprising a reaction mixture maintained at a first temperature; a second zone comprising a headspace above the reaction mixture into which humid gas migrating from the reaction mixture can migrate; and at least one diaphragm pressure transmitter, load cell, and/or scale in contact with the second zone, optionally comprising a membrane for detecting pressure in contact with the reaction container, detects the pressure exerted upon the reaction container by gases and fluids present in the second zone, and/or contacts the exterior surface of the reaction container is in communication with a control system for adjusting the pressure within the second zone in response to information received from diaphragm pressure transmitter, optionally wherein the control system continuously monitors information generated by the system, adjusts the pressure within the second zone using an exhaust pump, and/or is automated.

5. The system of any preceding claim, comprising:

a sterile filter between the at least one source of external heated air to the at least one exhaust line, and at least one second fluidic pathway connecting heated air that exits the sterile filter and the at least one exhaust line.

6. The system of any preceding claim wherein the heated air comprises a temperature sufficiently above that of the exhaust gas such that upon mixture of the external heated

air and the exhaust gas to produce a mixed exhaust gas, the relative humidity of the mixed exhaust gas is less than that of the exhaust gas.

7. The system of claim 6 wherein the relative humidity of the mixed exhaust gas is sufficiently low such that moisture from the mixed exhaust gas does not accumulate on the filter as the mixed exhaust gas exits the system.
8. A method for decreasing the relative humidity of an exhaust gas within a reaction system comprising traversing the exhaust gas through a system of any preceding claim.
9. A method for carrying out a reaction using a system of any preceding claim.