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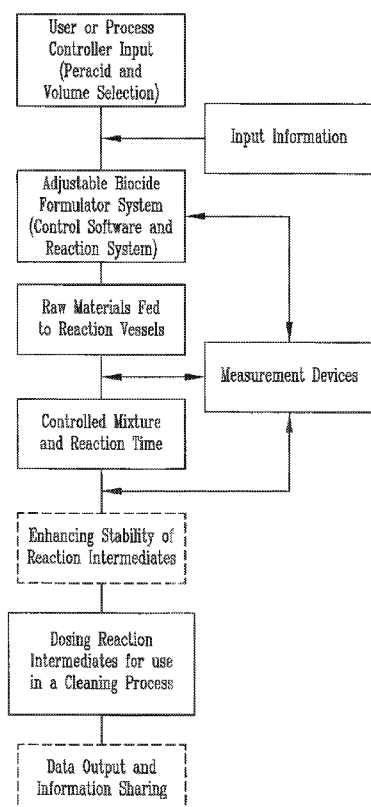
(54) **Title:** SUGAR ESTER PERACID ON-SITE GENERATOR AND FORMULATOR

Fig.1

(57) **Abstract:** Methods and systems for on-site generation of peracid chemistry, including temperature control of the same, namely peroxydicarboxylic acids and peroxydicarboxylic acid forming compositions, are disclosed. In particular, an adjustable biocide formulator or generator system is designed for on-site generation of peroxydicarboxylic acids and peroxydicarboxylic acid forming compositions from sugar esters. Methods of using the in situ generated peroxydicarboxylic acids and peroxydicarboxylic acid forming compositions are also disclosed.



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SUGAR ESTER PERACID ON-SITE GENERATOR AND FORMULATOR

FIELD OF THE INVENTION

5 The invention relates to methods and apparatus for on-site generation of peracids, namely peroxycarboxylic acids and peroxycarboxylic acid forming compositions for use as oxidizing agents. The invention further relates to methods and systems for temperature-controlled on-site generation of peracids. In particular, an adjustable biocide formulator or generator system is designed for on-site
10 generation of peroxycarboxylic acids and peroxycarboxylic acid forming compositions from at least one sugar ester in either a batch and/or continuous manner. Methods of using the in situ generated peroxycarboxylic acids and peroxycarboxylic acid forming compositions are also disclosed.

15 BACKGROUND OF THE INVENTION

Peracids, also known as peroxyacids, are known for use as sanitizers, disinfectants, deodorizers, and bleaching agents, among other uses. Peroxycarboxylic acids in particular are known for use as antimicrobials and bleaching agents. Peracids such as peroxycarboxylic acid have known chemical
20 disadvantages, namely, they are relatively instable in solution and decompose to ordinary oxyacids and oxygen.

Conventional peroxycarboxylic acid compositions are made through an acid catalyzed equilibrium reaction. Most often, the peroxycarboxylic acids are generated in a chemical plant, and then shipped to customers for on-site use. Due to
25 the limited storage stability of peroxycarboxylic acids they are often packed in special containers and shipped under the strict Department of Transportation (DOT) guidelines. Certain improvements to peroxycarboxylic acid stability have proved advantageous for shipping purposes, as described in U.S. Patent Application Serial No. 11/847,604, entitled "Shelf Stable, Reduced Corrosion, Ready to Use
30 Peroxycarboxylic Acid Antimicrobial Compositions," the entire contents of which are hereby expressly incorporated herein by reference.

Most commercially available products in an equilibrium mixture contain excess hydrogen peroxide in the presence of stabilizers and acid catalysts, to stabilize and improve the composition's shelf life. Despite stability improvements, excess amounts of reagents (*e.g.*, acids, oxidizing agents, and stabilizers) must be present in the compositions during shipping to prevent decomposition.

Peroxy-carboxylic acid instability, specifically limited storage stability, is described in detail in U.S. Patent Application Serial No. 12/262,935, entitled "Enhanced Stability Peracid Compositions," the entire contents of which are hereby expressly incorporated herein by reference.

Peracid generation is limited according to various kinetic reactions, including the temperature of the reaction. As a result, the generation of a peracid chemistry using the conventional acid catalyzed equilibrium reactions presents additional difficulties. In particular, changes in the ambient temperature of a location of a generator and/or of a raw starting material are expected to negatively impact the generation of peracid chemistry.

Accordingly, it is an objective of the claimed invention to develop methods and systems for on-site generation of peracids, including peroxy-carboxylic acid generating compositions and peroxy-carboxylic acids that are temperature insensitive.

Accordingly, it is an objective of the claimed invention to develop methods and systems for on-site generation of peracids, including peroxy-carboxylic acid generating compositions and peroxy-carboxylic acids. In particular it is an objective of the invention to for on-site generation of biocide and antimicrobial agent comprising individual or mixed peracid chemistries.

A further object of the invention is to develop a system for generation of individual or mixed peracid chemistries according to user-or system-specific needs.

A further object of the invention is to develop methods and systems for on-site generation of peracid chemistries to enhance efficacy performance, reduce transportation cost and hazards, reduce or eliminate wastes and enhance shelf-life of generated peracid chemistries.

A still further object of the invention is to develop a system for generation of peracid chemistries using sugar esters as backbone ingredients, which most preferably eliminates the use of builders and/or stabilizers.

Another object of the invention is to develop a system for peracid chemistry
5 generation on-site where the acid is decoupled from peracid formulations to enable acids to be selected based upon desired performance criteria.

A further object of the invention is to develop a system for generation of peracid chemistries which enables a process information backbone.

10 BRIEF SUMMARY OF THE INVENTION

An advantage of the invention is a system for on-site generation of a biocide or antimicrobial agent. The system may be formulated into a number of designs, including for example, a mobile cart or generator that is particularly suitable for the on-site generation of peracid chemistries required in batch formulations. It is a
15 particular advantage of the present invention that individual and/or mixed peracid chemistries, including peroxycarboxylic acid forming compositions or peroxycarboxylic acids are generated on-site according to particular needs of a user or system to provide desired performance against particular organisms, as well as providing desired volumes of the same chemistry. These benefits of the present
20 invention effectively eliminate the need for shipping and/or long-term stability of the product requiring the addition of various stabilizing agents thereby increasing the shipping, cost and formulation burdens.

In an embodiment, the present invention is an adjustable biocide formulator or generator system for on-site peroxycarboxylic acid forming composition
25 generation including an apparatus with at least one reaction vessel, a series of feed pumps, and an outlet for dosing a peroxycarboxylic acid forming composition. In an embodiment the feed pumps are in fluid connection with the reaction vessel and supply reagents to produce the peroxycarboxylic acid forming composition and the reagents may include an ester of a polyhydric alcohol and a C1 to C18 carboxylic
30 acid, a source of alkalinity an oxidizing agent and other reagents according to the invention. In an embodiment the reaction vessel is in fluid connection with the outlet to dispense the peroxycarboxylic acid forming composition, which may be an

individual or mixed peroxycarboxylic acid forming composition as selected by a user- or system-inputted selection.

In an embodiment, the present invention is an adjustable biocide formulator or generator system for on-site peroxycarboxylic acid forming composition generation including an apparatus with a continuous or in-line reaction vessel, a series of feed pumps for providing reagents for forming the peroxycarboxylic acid forming composition, and an outlet for dosing a peroxycarboxylic acid forming composition. In an embodiment the feed pumps are in fluid connection with the reaction vessel and supply reagents to produce the peroxycarboxylic acid forming composition and the reagents may include an ester of a polyhydric alcohol and a C1 to C18 carboxylic acid, a source of alkalinity, an oxidizing agent, and additional reagents according to the invention. In an embodiment the reaction vessel is in fluid connection with the outlet to dispense the peroxycarboxylic acid forming composition, which may be an individual or mixed peroxycarboxylic acid forming composition as selected by a user- or system-inputted selection.

In a further embodiment, the present invention is a temperature controlled adjustable biocide formulator or generator system for on-site peroxycarboxylic acid forming composition generation comprising: an apparatus for producing peroxycarboxylic acid forming composition that is insensitive to environmental temperatures of the location of the apparatus and/or reagents comprising a reaction vessel, a series of feed pumps, an outlet for dosing a peroxycarboxylic acid forming composition from said reaction vessel and a controller for a user- or system-inputted selection device; a temperature controlled mechanism for maintaining a controlled temperature of said reaction vessel and/or one or more reagents, wherein said reagents comprise an ester of a polyhydric alcohol and a C1 to C18 carboxylic acid, a source of alkalinity and an oxidizing agent; wherein said feed pumps are in fluid connection with said reaction vessel and supply one or more reagents to produce said peroxycarboxylic acid forming composition in said reaction vessel; and

In an embodiment, the present invention is a method for on-site, temperature controlled peroxycarboxylic acid forming composition generation or peroxycarboxylic acid generation comprising: inputting a user-desired or system-controlled peroxycarboxylic acid forming composition or peroxycarboxylic acid

formulation into a control software for on-site generation, wherein said input formulation selects an individual or mixed peroxydicarboxylic acid forming composition or peroxydicarboxylic acid and corresponding volume or mass for on-site generation; and combining one or more sugar esters of a polyhydric alcohol and a C1 to C18 carboxylic acid, a source of alkalinity and an oxidizing agent at alkaline pH in an adjustable biocide formulator or generator system at a pH above at least 12, wherein said system is an apparatus that is insensitive to environmental temperatures of the location of the apparatus and/or reagents comprising a reaction vessel, a series of feed pumps, an outlet for dosing a peroxydicarboxylic acid forming composition from said reaction vessel and a controller for a user- or system-inputted selection device; and generating a peroxydicarboxylic acid forming composition or peroxydicarboxylic acid formulation; wherein said temperature insensitivity to the environmental temperatures of the location of the apparatus and/or reagents is controlled by a mechanism for maintaining a controlled temperature of said reaction vessel and/or one or more reagents; wherein said feed pumps are in fluid connection with said reaction vessel and supply one or more reagents to produce said peroxydicarboxylic acid forming composition in said reaction vessel; and wherein said reaction vessel is in fluid connection with said outlet to dispense said peroxydicarboxylic acid forming composition.

In a further embodiment, the present invention is a method for on-site peroxydicarboxylic acid forming composition or peroxydicarboxylic acid generation and may include the steps of inputting a user- or system-controlled peroxydicarboxylic acid forming composition or peroxydicarboxylic acid formulation into a control software for an adjustable biocide formulator or generator system, and mixing one or more sugar esters of a polyhydric alcohol and a C1 to C18 carboxylic acid, a source of alkalinity and an oxidizing agent at alkaline pH in an adjustable biocide formulator or generator system. In an embodiment the input formulation selects an individual or mixed peroxydicarboxylic acid forming composition or peroxydicarboxylic acid and corresponding volume or mass for onsite generation.

The methods of the invention further include the steps of diluting a source of alkalinity to a target concentration. The methods further include the steps of adding

the ester(s) downstream (e.g. after the addition of the diluted alkalinity source solution).

In a further embodiment, the present invention is a method of cleaning using an on-site generated peroxy-carboxylic acid forming composition and may include
5 obtaining a user- or system-inputted peroxy-carboxylic acid forming composition on-site using an adjustable biocide formulator or generator system and applying the peroxy-carboxylic acid forming composition in an amount sufficient to sanitize, bleach or disinfect a surface in need thereof.

While multiple embodiments are disclosed, still other embodiments of the
10 present invention will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the invention. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

15 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a schematic diagram of a user or controller operated adjustable biocide formulator apparatus according to the invention.

FIG. 2 shows a diagram of an embodiment of an adjustable biocide formulator apparatus according to the invention using a single reaction vessel.

20 FIG. 3 shows a diagram of an alternative adjustable biocide formulator apparatus according to an embodiment of the invention using multiple reaction vessels.

FIG. 4 shows a diagram of a multiple reaction vessel embodiment for the adjustable biocide formulator apparatus according to an embodiment of the
25 invention.

FIG. 5 shows a diagram of an embodiment of an adjustable biocide formulator apparatus according to the invention wherein a controller is included as a feature of the apparatus.

FIG. 6 shows a diagram of an embodiment of an adjustable biocide
30 formulator apparatus according to the invention wherein a plurality of pumps dosing

raw starting materials (e.g. reagents) are provided to a reaction vessel (e.g. manifold).

FIG. 7 shows a diagram of an embodiment of the adjustable biocide formulator apparatus according to the invention.

5 FIGS. 8A-B shows a diagram of an additional embodiment of the adjustable biocide formulator apparatus according to an embodiment of the invention.

FIG. 9 shows a diagram of an embodiment of an adjustable biocide formulator apparatus according to the invention wherein a controller is included as a feature of the apparatus.

10 FIGS. 10A-B show diagrams of an embodiment of an adjustable biocide formulator apparatus according to the invention, including description of the dosing of raw starting materials (e.g. reagents) for the generation of peracid chemistries according to the invention.

FIG. 11 shows a graph representing POOA concentration over time at various reaction temperatures according to various embodiments of the adjustable biocide formulator apparatus according to the invention.

FIG. 12 shows a graph representing POOA production using the adjustable biocide formulator apparatus according to the invention at various temperatures over a period of time.

20 FIG. 13 shows a graph representing POOA production and temperature as a function of time according to various embodiments of the invention.

Various embodiments of the present invention will be described in detail with reference to the drawings, wherein like reference numerals represent like parts throughout the several views. Reference to various embodiments does not limit the scope of the invention. Figures represented herein are not limitations to the various
25 embodiments according to the invention and are presented for exemplary illustration of the invention.

DETAILED DESCRIPTION OF THE INVENTION

30 The present disclosure relates to adjustable biocide formulator or generator systems for on-site peracid generation, including for example peroxycarboxylic acid forming compositions or peroxycarboxylic acids, as well as methods of making and

using such compositions. The compositions and systems for making the compositions disclosed herein have many advantages over conventional systems and methods for making peroxydicarboxylic acids or peroxydicarboxylic acid forming compositions. For example, the systems allow on-site, user- or system-controlled
5 formulation, eliminating the step of shipping hazardous peroxydicarboxylic acid compositions to an end user. In addition, there are various advantages of the compositions, including having significantly lower levels of reactant residues compared to peroxydicarboxylic acid compositions generated using equilibrium reactions, increased stability and ability to be generated in situ and/or on site.

10 The embodiments of this invention are not limited to particular methods and systems for on-site generation of sugar ester peracids for use as biocides, which can vary and are understood by skilled artisans. It is further to be understood that all terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting in any manner or scope. For example, as
15 used in this specification and the appended claims, the singular forms "a," "an" and "the" can include plural referents unless the content clearly indicates otherwise. Further, all units, prefixes, and symbols may be denoted in its SI accepted form. Numeric ranges recited within the specification are inclusive of the numbers defining the range and include each integer within the defined range.

20 So that the present invention may be more readily understood, certain terms are first defined. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which embodiments of the invention pertain. Many methods and materials similar, modified, or equivalent to those described herein can be used in the practice
25 of the embodiments of the present invention without undue experimentation, the preferred materials and methods are described herein. In describing and claiming the embodiments of the present invention, the following terminology will be used in accordance with the definitions set out below.

The term "about," as used herein, refers to variation in the numerical quantity
30 that can occur, for example, through typical measuring and liquid handling procedures used for making concentrates or use solutions in the real world; through inadvertent error in these procedures; through differences in the manufacture,

source, or purity of the ingredients used to make the compositions or carry out the methods; and the like. The term "about" also encompasses amounts that differ due to different equilibrium conditions for a composition resulting from a particular initial mixture. Whether or not modified by the term "about", the claims include
5 equivalents to the quantities.

As used herein, "agricultural" or "veterinary" objects or surfaces include animal feeds, animal watering stations and enclosures, animal quarters, animal veterinarian clinics (*e.g.* surgical or treatment areas), animal surgical areas, and the like.

10 As used herein, the phrase "air streams" includes food anti-spoilage air circulation systems. Air streams also include air streams typically encountered in hospital, surgical, infirmity, birthing, mortuary, and clinical diagnosis rooms.

The term "cleaning," as used herein, means to perform or aid in soil removal, bleaching, microbial population reduction, or combination thereof.

15 As used herein, the term "disinfectant" refers to an agent that kills all vegetative cells including most recognized pathogenic microorganisms, using the procedure described in A.O.A.C. Use Dilution Methods, Official Methods of Analysis of the Association of Official Analytical Chemists, paragraph 955.14 and applicable sections, 15th Edition, 1990 (EPA Guideline 91-2). As used herein, the
20 term "high level disinfection" or "high level disinfectant" refers to a compound or composition that kills substantially all organisms, except high levels of bacterial spores, and is effected with a chemical germicide cleared for marketing as a sterilant by the Food and Drug Administration. As used herein, the term "intermediate-level disinfection" or "intermediate level disinfectant" refers to a compound or
25 composition that kills mycobacteria, most viruses, and bacteria with a chemical germicide registered as a tuberculocide by the Environmental Protection Agency (EPA). As used herein, the term "low-level disinfection" or "low level disinfectant" refers to a compound or composition that kills some viruses and bacteria with a chemical germicide registered as a hospital disinfectant by the EPA.

30 As used herein, the phrase "food processing surface" refers to a surface of a tool, a machine, equipment, a structure, a building, or the like that is employed as part of a food processing, preparation, or storage activity. Examples of food

processing surfaces include surfaces of food processing or preparation equipment (*e.g.*, slicing, canning, or transport equipment, including flumes), of food processing wares (*e.g.*, utensils, dishware, wash ware, and bar glasses), and of floors, walls, or fixtures of structures in which food processing occurs. Food processing surfaces are
5 found and employed in food anti-spoilage air circulation systems, aseptic packaging sanitizing, food refrigeration and cooler cleaners and sanitizers, ware washing sanitizing, blancher cleaning and sanitizing, food packaging materials, cutting board additives, third-sink sanitizing, beverage chillers and warmers, meat chilling or scalding waters, autodish sanitizers, sanitizing gels, cooling towers, food processing
10 antimicrobial garment sprays, and non-to-low-aqueous food preparation lubricants, oils, and rinse additives.

As used herein, the phrase "food product" includes any food substance that might require treatment with an antimicrobial agent or composition and that is edible with or without further preparation. Food products include meat (*e.g.*, red meat and
15 pork), seafood, poultry, produce (*e.g.*, fruits and vegetables), eggs, living eggs, egg products, ready to eat food, wheat, seeds, roots, tubers, leafs, stems, corns, flowers, sprouts, seasonings, or a combination thereof. The term "produce" refers to food products such as fruits and vegetables and plants or plant-derived materials that are typically sold uncooked and, often, unpackaged, and that can sometimes be eaten
20 raw.

As used herein, the term "fouling" shall be understood to mean the undesirable presence of or any deposition of any organic or inorganic material in the applicable composition or chemistry.

As used herein, the term "free" or "substantially free" refers to a
25 composition, mixture, or ingredient that does not contain a particular compound or to which a particular compound or a particular compound-containing compound has not been added. Should the particular compound be present through contamination and/or use in a minimal amount of a composition, mixture, or ingredients, the amount of the compound shall be less than about 3 wt-%. More preferably, the
30 amount of the compound is less than 2 wt-%, less than 1 wt-%, and most preferably the amount of the compound is less than 0.5 wt-%.

As used herein, the phrase “health care surface” refers to a surface of an instrument, a device, a cart, a cage, furniture, a structure, a building, or the like that is employed as part of a health care activity. Examples of health care surfaces include surfaces of medical or dental instruments, of medical or dental devices, of
5 electronic apparatus employed for monitoring patient health, and of floors, walls, or fixtures of structures in which health care occurs. Health care surfaces are found in hospital, surgical, infirmity, birthing, mortuary, and clinical diagnosis rooms. These surfaces can be those typified as “hard surfaces” (such as walls, floors, bed-pans, etc.), or fabric surfaces, *e.g.*, knit, woven, and non-woven surfaces (such as surgical
10 garments, draperies, bed linens, bandages, etc.), or patient-care equipment (such as respirators, diagnostic equipment, shunts, body scopes, wheel chairs, beds, etc.), or surgical and diagnostic equipment. Health care surfaces include articles and surfaces employed in animal health care.

As used herein, the term “instrument” refers to the various medical or dental
15 instruments or devices that can benefit from cleaning with a composition according to the present invention. As used herein, the phrases “medical instrument,” “dental instrument,” “medical device,” “dental device,” “medical equipment,” or “dental equipment” refer to instruments, devices, tools, appliances, apparatus, and equipment used in medicine or dentistry. Such instruments, devices, and equipment
20 can be cold sterilized, soaked or washed and then heat sterilized, or otherwise benefit from cleaning in a composition of the present invention. These various instruments, devices and equipment include, but are not limited to: diagnostic instruments, trays, pans, holders, racks, forceps, scissors, shears, saws (*e.g.* bone saws and their blades), hemostats, knives, chisels, rongeurs, files, nippers, drills,
25 drill bits, rasps, burrs, spreaders, breakers, elevators, clamps, needle holders, carriers, clips, hooks, gouges, curettes, retractors, straightener, punches, extractors, scoops, keratomes, spatulas, expressors, trocars, dilators, cages, glassware, tubing, catheters, cannulas, plugs, stents, scopes (*e.g.*, endoscopes, stethoscopes, and arthoscopes) and related equipment, and the like, or combinations thereof.

30 As used herein, the term “microorganism” refers to any noncellular or unicellular (including colonial) organism. Microorganisms include all prokaryotes. Microorganisms include bacteria (including cyanobacteria), spores, lichens, fungi,

protozoa, virinos, viroids, viruses, phages, and some algae. As used herein, the term “microbe” is synonymous with microorganism.

As used herein, the terms “mixed” or “mixture” when used relating to “peracids,” “peroxycarboxylic acid composition” or “peroxycarboxylic acids” refer to a composition or mixture including more than one peroxycarboxylic acid, such as a composition or mixture including peroxyacetic acid (POAA) and peroxyoctanoic acid (POOA).

As used herein, the terms “mixed,” “mixture” or “more than one” when used relating to esters suitable for use in forming the compositions of the invention refer to a composition or mixture including more than one ester group undergoing a perhydrolysis reaction to form the peroxycarboxylic composition. The use of at least one ester of a polyhydric alcohol and a C1 to C18 carboxylic acid according to the invention includes the use of various forms of the ester, such as the mono, di, tri and/or mixtures thereof formations of the particular ester. Accordingly, examples of suitable forms of esters for use as “mixtures” or comprising “more than one” include, but are not limited to, glycerol monoctanoate, glycerol dioctanoate, glycerol trioctanoate, sorbitan monoctanoate, sorbitan dioctanoate, sorbitan trioctanoate, and mixtures and derivatives thereof. Further, as one skilled in the art shall ascertain based upon the description of the invention disclosed herein, the use of an ester source, such as glycerol octanoate, may further comprise the use of the mono, di and tri esters and/or mixtures thereof. According to various embodiments of the invention, the use of “an” ester, such as octanoic glyceride, may include the use of a “mixture” of esters wherein more than one formation of the ester is present, including for example the mono, di and tri formations and/or mixtures thereof.

As used herein, the phrases “objectionable odor,” “offensive odor,” or “malodor,” refer to a sharp, pungent, or acrid odor or atmospheric environment from which a typical person withdraws if they are able to. Hedonic tone provides a measure of the degree to which an odor is pleasant or unpleasant. An “objectionable odor,” “offensive odor,” or “malodor” has an hedonic tone rating it as unpleasant as or more unpleasant than a solution of 5 wt-% acetic acid, propionic acid, butyric acid, or mixtures thereof.

As used herein, the terms "peracid" or "peroxy acid" refer to an acid having the hydrogen of the hydroxyl group replaced by a hydroxy group. Oxidizing peracids are referred to herein as peroxycarboxylic acids.

As used herein, the term "polyhydric alcohol" or "polyol," refers to an
5 alcohol that has two or more hydroxyl groups. Polyhydric alcohols suitable for use in the compositions include, but are not limited to, sugars, sugar alcohols, and mixtures and derivatives thereof.

As used herein, the term "sanitizer" refers to an agent that reduces the number of bacterial contaminants to safe levels as judged by public health
10 requirements. In an embodiment, sanitizers for use in this invention will provide at least a 99.999% reduction (5-log order reduction). These reductions can be evaluated using a procedure set out in Germicidal and Detergent Sanitizing Action of Disinfectants, Official Methods of Analysis of the Association of Official Analytical Chemists, paragraph 960.09 and applicable sections, 15th Edition, 1990
15 (EPA Guideline 91-2). According to this reference a sanitizer should provide a 99.999% reduction (5-log order reduction) within 30 seconds at room temperature, 25 +/- 2 °C, against several test organisms.

For the purpose of this patent application, successful microbial reduction is achieved when the microbial populations are reduced by at least about 50%, or by
20 significantly more than is achieved by a wash with water. Larger reductions in microbial population provide greater levels of protection.

Differentiation of antimicrobial "-cidal" or "-static" activity, the definitions which describe the degree of efficacy, and the official laboratory protocols for measuring this efficacy are considerations for understanding the relevance of
25 antimicrobial agents and compositions. Antimicrobial compositions can affect two kinds of microbial cell damage. The first is a lethal, irreversible action resulting in complete microbial cell destruction or incapacitation. The second type of cell damage is reversible, such that if the organism is rendered free of the agent, it can again multiply. The former is termed microbiocidal and the later, microbistatic. A
30 sanitizer and a disinfectant are, by definition, agents which provide antimicrobial or microbiocidal activity. In contrast, a preservative is generally described as an inhibitor or microbistatic composition.

As used herein the term “sugar” refers to carbohydrates including one, two, or more saccharose groups. Sugars are a group of organic compounds related by molecular structure that comprise simpler members of the general class of carbohydrates. Each sugar consists of a chain of 2 to 7 carbon atoms (usually 5 or 6).

5 Sugars have the general formula $C_nH_{2n}O_n$, wherein n is between 2 and 7. One of the carbons carries aldehydic or ketonic oxygen which may be combined in acetal or ketal forms and the remaining carbon atoms usually bear hydrogen atoms and hydroxyl groups. In general, sugars are more or less sweet, water soluble, colorless, odorless, optically active substances which lose water, caramelize and char when

10 heated. Exemplary sugars include, but are not limited to, glucose, sucrose, lactose and mixtures thereof.

As used herein, the term “sugar alcohol” refers to the hydrogenated form of a carbohydrate, wherein the carbonyl group of the carbohydrate has been reduced to a primary or secondary hydroxyl group. Sugar alcohols have the general formula

15 $CH_2OH(CHOH)_nCH_2OH$, wherein n is from 2 to 5. Exemplary sugar alcohols include, but are not limited to, glycol, ethylene glycol, propylene glycol, glycerol, erythritol, pentaerythritol, threitol, arabitol, xylitol, ribitol, mannitol, sorbitol, sorbitan, dulcitol, iditol, inositol, isomalt, maltitol, lactitol, polyglycitol, 1,4-cyclohexane diol, and mixtures and derivatives thereof. In some embodiments, the

20 sugar alcohol is selected from ethylene glycol, propylene glycol, glycerol, polyglycerol, sorbitol, sorbitan, and mixtures and derivatives thereof.

As used herein, the term “ware” refers to items such as eating and cooking utensils, dishes, and other hard surfaces such as showers, sinks, toilets, bathtubs, countertops, windows, mirrors, transportation vehicles, and floors. As used herein,

25 the term “warewashing” refers to washing, cleaning, or rinsing ware. Ware also refers to items made of plastic. Types of plastics that can be cleaned with the compositions according to the invention include but are not limited to, those that include polycarbonate polymers (PC), acrylonitrile-butadiene-styrene polymers (ABS), and polysulfone polymers (PS). Another exemplary plastic that can be

30 cleaned using the compounds and compositions of the invention include polyethylene terephthalate (PET).

As used herein, the term "waters" includes food process or transport waters. Food process or transport waters include produce transport waters (*e.g.*, as found in flumes, pipe transports, cutters, slicers, blanchers, retort systems, washers, and the like), belt sprays for food transport lines, boot and hand-wash dip-pans, third-sink
5 rinse waters, and the like. Waters also include domestic and recreational waters such as pools, spas, recreational flumes and water slides, fountains, and the like.

The term "weight percent," "wt-%," "percent by weight," "% by weight," and variations thereof, as used herein, refer to the concentration of a substance as the weight of that substance divided by the total weight of the composition and
10 multiplied by 100. It is understood that, as used here, "percent," "%," and the like are intended to be synonymous with "weight percent," "wt-%," etc.

Embodiments of the Invention

According to an embodiment of the invention methods and apparatus for on-site generation of peracid chemistries for use as cleaning agents, including for
15 example, antimicrobial applications, bleaching applications, and other cleaning and anti-scaling applications. The methods and apparatus according to the invention are capable of on-site generation of both individual or mixed peracid chemistries formulated according to user-specifications in either batch and/or a continuous manner. In one aspect, the methods and apparatus according to the invention
20 provide for continuous generation of the particular chemistries selected by a user. In addition, the methods and apparatus provide for the generation of large volumes of the user selected chemistries. Beneficially, the methods and apparatus according to the invention may be used at flow rates varying from mL per minute to liters per minute. For example, various embodiments of the invention (including as set forth
25 in the Examples) use flow rates of approximately 25 mL/minute and can be scaled up to rates as great as liters/minute.

The invention overcomes the shortfalls of commercially-available peracids by providing user-specific formulations with enhanced performance efficacy through a non-equilibrium methods of making. In addition, the methods and
30 apparatus use sugar esters as backbone ingredients to generate on-site peracid chemistries, beneficially reducing the costs and hazards associated with transporting active chemistries, providing active chemistries with increased shelf-lives and

reduction of waste of active chemistries as a result of on-site user-identified peracid production according to the invention.

The methods and apparatus of the present invention overcome significant limitations of conventional methods of peracid (*i.e.* peroxy-carboxylic acid) generation, typically acid catalyzed equilibrium reactions. The methods and apparatus of the present invention overcome the many downsides to such conventional methods, including, but not limited to elimination of the use of excess amounts of reactants, and hazardous shipping conditions.

The methods and apparatus of the present invention further overcomes a significant limitation of using any adjustable biocide formulator or generator system disclosed therein – namely, temperature adjustments for the efficient and cost-effective use of any adjustable biocide formulator or generator system. Temperature is a critical factor on the kinetics of both peracid production as well as the kinetics of peracid decomposition inside any adjustable biocide formulator or generator system. In particular, temperature becomes important when considering the variable environments in which an ex-situ peracid adjustable biocide formulator or generator system may be used. Often environments suitable for employing an adjustable biocide formulator or generator system might range in temperature from the very cold (e.g. about 34°F (1°C)) to the very hot (e.g. about 122°F (50°C)). Exemplary on-site locations for generation of the peracid chemistry according to the invention may include, for example, a cold or refrigerated dairy room. Alternatively, a warm ambient temperature would be expected from a process floor of a manufacturing plant where myriad of heat-generating machines are located. As a result, when an adjustable biocide formulator or generator system and the particular raw starting materials (e.g. reagents) are used under these variable conditions they produce unique peracid production and degradation curves which impact the ability to consistently deliver a required dose of chemistry. Establishing methods for eliminating these varying production and/or degradation curves overcomes a significant limitation and results in the consistent generation of peracid chemistries regardless of ambient temperature conditions.

According to an embodiment of the invention, the methods of the invention solve the problem caused by having variable reaction temperatures, which can

negatively impact the output and stability of an ex-situ peracid reaction. According to the invention, the ABF systems and methods of use are insensitive to environmental (e.g. ambient) temperatures of the location of the apparatus and/or reagents used for the generation of peracid chemistry. In particular, in one aspect the invention temperature controls are provided for the reaction vessel and/or reaction manifold to overcome (i.e. control) any variability in both environmental factors and heat generated during the progression of the reaction. In another aspect of the invention, temperature controls are provided to at least one raw starting material (e.g. reagent) that is input into an adjustable biocide formulator or generator system. According to additional embodiments a combination of temperature controls may be provided.

While an understanding of the mechanism is not necessary to practice the present invention and while the present invention is not limited to any particular mechanism of action, it is contemplated that, in some embodiments the benefits afforded according to the invention result from the production of a non-equilibrium chemistry using the methods and apparatus of the present invention. Beneficially, the reacted peracids according to the invention are obtained in greater amounts than in equilibrium chemistry wherein greater amounts of unreacted hydrogen peroxide and other reagents would be present. According to the present invention, an aqueous solution of the peroxycarboxylic acid(s) produced contains a relatively higher concentration of peroxycarboxylic acid(s) compared to unreacted hydrogen peroxide component. This is significantly advantageous for the anti-microbial and other cleaning applications disclosed herein as desirable according to the embodiments of the invention.

Rather than providing a peracid composition in an equilibrium mixture, in situ generation of the peracid composition allows the peracids to be produced stoichiometrically through selecting the composition of the starting materials. The in situ systems according to the invention therefore generate higher concentrations of the peroxycarboxylic acid(s) than are available in equilibrium systems. In particular, according to the invention the systems generate higher concentrations of the peroxycarboxylic acid(s) and lower concentrations of hydrogen peroxide (e.g. unreacted reagents) than achieved in equilibrium systems. In addition, the methods

of the present invention generate peroxycarboxylic acid(s) under alkaline conditions and thereafter adjust to acidic conditions to stabilize the peroxycarboxylic acid(s) and ensure the peroxycarboxylic acid(s) compositions do not disassociate.

System for Making On-Site Peracid Compositions

5 In some aspects, the present invention relates to an adjustable biocide formulator or generator (ABF) apparatus or system for on-site generation of peracid chemistries. As used herein, the terms ABF, ABF system/apparatus/generator and the like refer equally to the various embodiments of the invention disclosing the adjustable
10 biocide formulator, apparatus and/or system disclosed herein according to the various embodiments. The ABF system produces peroxycarboxylic acid forming compositions according to the disclosure presented herein. Peroxycarboxylic acid forming compositions refer to the generation of peroxycarboxylic acids in situ, in a non-equilibrium reaction. In particular embodiments of the invention, the system
15 produces the anion capable of forming peroxycarboxylic acid upon acidification. According to additional aspects of the invention, the ABF system may produce peroxycarboxylic acids.

Batch Preparations

20 In some aspects, the system for on-site generation of peroxycarboxylic acid forming compositions may comprise, consist of and/or consist essentially of an apparatus including at least one reaction vessel, a series of feed pumps and an outlet for dosing the generated chemistry from the reaction vessel. In some aspects, the reaction vessels, series of feed pumps and the outlet are in fluid connection to provide the reagents used to generate the peroxycarboxylic acid forming
25 composition in the reaction vessel. In some aspects, the system may also include one or more reservoirs in fluid connection with the reaction vessels to allow further mixing and/or storage of the peroxycarboxylic acid forming compositions. In some aspects, the system may optionally comprise at least one measurement device and/or at least one mechanism suitable for mixing the reagents in the reaction vessel(s).

30 In some aspects of the invention, the reaction vessel meets the hydraulic requirements of the peracid reaction kinetics. Although not intending to be limited by a particular theory of the invention, the kinetics of the perhydrolysis reaction

according to the invention are pH, concentration and/or temperature dependent, and the reaction can reach the maximum yield in the order of minutes. The reaction vessel may be designed in a variety of ways, including for example shape, size, temperature, fluid dynamics (*e.g.* recirculating or other means of modifying the hydraulics of the system) and material.

According to an embodiment of the invention, the reaction vessel may have a convex shape at the bottom to assist in drainage of its contents and assist with mixing of the contents. In addition, the reaction vessels and the system may also employ mixers, such as an impeller, or the like as one skilled in the art will appreciate, for circulation within the reaction vessel, circulation pumps or be gravity-driven, employ additional holding vessels, reagent delivery sensors (*e.g.* proof of reagent and/or peracid chemistry delivery sensor) or combinations of the same to meet the peracid reaction kinetics of the system.

Continuous Preparations

In some aspects, the ABF system according to the present invention provides an apparatus designed to produce peracid chemistry in a continuous manner, rather than in batch modes. In addition, the continuous manner of peracid generation provides for the supply of chemistries in large quantities and production rates. According to the invention, there are numerous applications for the apparatus and methods of the present invention having increased chemical use demands requiring modifications to enable continuous chemistry generation.

The ABF systems and methods according to the invention obviate the need for larger-sized reactors and/or increasing the number of reactors and requiring staggering-start modes as previously required in the first generation ABF systems disclosed in U.S. patent application Serial No. 61/427,951 (Attorney Docket Numbers 2839USP1 and 2839USU1), entitled Sugar Ester Peracid On-Site Generator and Formulator. Further, the present invention significantly simplifies the ABF apparatus through the elimination of various apparatus components as a result of apparatus design (*e.g.* valves, mixers, vessels, etc. and combinations of the same). The ability to simplify the ABF system and eliminate numerous components results from the use of the pump system and the modified reaction vessel (*e.g.* reaction manifold).

In some aspects, the system for on-site generation of peroxycarboxylic acid forming compositions may comprise, consist of and/or consist essentially of an apparatus including at least one reaction vessel, a series of feed pumps and an outlet for dosing the generated chemistry from the reaction vessel. According to
5 embodiments of the invention, the reaction vessel, as used herein, describes a variable length, tubing diameter, tubing material and flow pattern of a reaction tubing or manifold, as one skilled in the art will understand from the disclosure of the present invention. The terms “reaction vessel,” “reaction manifold” and the like shall be understood to refer to the location of the perhydrolysis reaction according to
10 the invention. Preferably, the reaction manifold is embodied as a flow through reactor for the perhydrolysis reaction according to the invention.

In some aspects, the reaction manifold, series of feed pumps and the outlet are in fluid connection to provide the raw starting materials (e.g. reaction reagents) used to generate the peroxycarboxylic acid forming composition in the reaction
15 manifold. In some aspects, the system may also include one or more reservoirs in fluid connection with the reaction manifold to allow further mixing and/or storage of the peroxycarboxylic acid forming compositions. In some aspects, the system may optionally comprise at least one measurement device.

In some aspects, the delivery rates of the reagents are balanced against the
20 chemical demand of the application. In particular, the reaction manifold is sized by selecting the appropriate reactor length and inner diameter (volume) to achieve proper reaction time for the specified chemistry.

In some aspects of the invention the ABF system does not include any systems or components for mixing the reagents in the reaction manifold (e.g. mixers,
25 impellers or the like). Beneficially, the design of the reaction manifold obviates the need for such components as a result of the length and/or shape of the reaction manifold. Instead, the pumping of raw starting materials through the reaction manifold is sufficient for mixing of the components for the perhydrolysis reaction to take place. Alternatively, additional modifications to the reaction manifold can be
30 made to further assist in mixing of the reagents, such as using baffles, continuous stirred-tank reactors (CSTR) or other means for interrupting the flow of liquid (e.g. disrupting the laminar flow through the reaction manifold). As one skilled in the art

of chemistry reaction kinetics will ascertain, the use of variable pumps and injection manifolds for providing the reagents can be varied to adjust the rate and amount of reagents added to a particular system.

5 In some aspects an injection manifold is provided to source individual reagents for the chemistry generation according to the invention. In alternative aspects of the invention, an injection manifold may have fewer inputs into the system, as reagents may be combined into one or more premixes. One skilled in the art will ascertain that the variability in the construction and design of the injection manifold for providing the reagents to the reaction manifold of the system. For
10 example, one or more injection manifolds may be incorporated into a system to provide reagents at different times and/or locations of the reaction manifold (e.g. to time the addition of the sugar esters for the production of mixed peracid chemistries). These and other modifications of the system are within the scope of the invention and will be appreciated by a skilled artisan.

15 In some aspects of the invention, the reaction manifold meets the hydraulic requirements of the peracid reaction kinetics. Although not intending to be limited by a particular theory of the invention, the kinetics of the perhydrolysis reaction according to the invention are pH, concentration and/or temperature dependent, and the reaction can reach the maximum yield in the order of minutes. The reaction
20 manifold and components of the ABF system may be designed in a variety of ways, including for example shape, size, temperature, fluid dynamics (e.g. pumping or other means to modify the hydraulics of the system) and material.

In additional aspects of the invention, the pumps providing the reagents into an injection manifold may be pressurized. In a preferred embodiment, the pumps
25 create a pressure differential within the feed pumps and/or reaction manifolds. The systems according to the invention may further include a pressure gauge to measure such pressure differential and provide system feedback for adjusting the pressure created by the pumps. For purposes of improving the pressure within a system, the apparatus may further include the use of an injection quill to ensure the movement
30 of reagents through the feed pumps and/or reaction manifold with the highest velocity.

Additional Aspects of On-Site Generation According to the Invention

In some aspects of the invention, the systems for on-site generation of peroxycarboxylic acid forming compositions may include at least one measurement device or a plurality of measurement devices. Such measurement devices are those suitable to measure one or more reaction kinetics or system operations for the generation of peroxycarboxylic acid forming compositions, including for example devices to measure fluorescence, weight, flow (*e.g.* flow meters or switches), capacitive level, pH, oxidation reduction potential, pressure, temperature and combinations thereof. Such measurement devices may measure the system's feed pumps, reaction vessels, reservoir, outlets, etc.

Examples of additional suitable measurement devices include capacitive level sensors, out of product alarms, POA / peroxide monitors, oxychecks, IR / UV / VIS spectroscopy and pressure switches. Still further examples of suitable measurement devices are disclosed herein, in addition various embodiments of those disclosed in U.S. patent application Serial No. 12/108,202, and U.S. Patent No. 7,547,421, both entitled Apparatus and Method for Making Peroxycarboxylic Acid, which are herein incorporated by reference in their entirety.

In some embodiments of the invention, the system provides an acid source for the acidification step to take place in the ABF system. The acid source may be an acid or an aqueous acid solution. As a result the peroxycarboxylic acid forming composition is acidified to peroxycarboxylic acid within the system. In an embodiment of the invention, the system may include a feed pump to provide an acid or acidic aqueous solution in fluid communication with one or more reaction vessels or reservoirs. The addition of the acid or acidic aqueous solution may dilute the peroxycarboxylic acid forming composition to form a peroxycarboxylic acid having a pH of about 1.0 to about 8.0. As a result, a stabilized formulation is generated by the system. According to certain embodiments, the addition of the acid or acidic aqueous solution produces peracid formulations with increased stability. However, as one skilled in the art will appreciate, some reaction intermediates are stable for longer periods of time and do not need to be quenched with acid immediately. For example, some reaction intermediates are stable for at least 24 hours and can be pumped to a sump reservoir for dosing into a cleaning process or dosed directly from a reaction vessel. Other peroxycarboxylic acid forming

compositions are less stable and the perhydrolysis reaction requires quenching with the acid or acidic aqueous solution to lower the pH and stabilize more promptly.

According to alternative embodiments of the invention, the ABF system generates peroxycarboxylic acid forming compositions which are acidified outside
5 of the system (*i.e.*, post generator within a customer's process). For example, post-generator acidification may include a clean in place (CIP) process where the peroxycarboxylic acid forming composition (anion solution) is pumped to a temporary holding tank for use in a CIP system, or pumped directly to a CIP system where the acid is added either in a pipe or the CIP vessel itself. A further example
10 of post-generator acidification may include a healthcare application or certain laundry applications where the acid is added to provide a peroxycarboxylic acid (with an acid pH) to provide bleaching and/or sanitizing benefits of the peracid.

According to additional embodiments of the invention, there are various applications for the compositions of the invention where acidification is not required
15 and/or desired as the use of the peroxycarboxylic acid forming composition (anion solution) is preferred. For example, in a laundry application the acid is not be added in order to benefit from the alkaline pH of the anion for bleaching purposes. The alkaline pH for bleaching is obtained from the anion species, as a result the peroxycarboxylic acid forming composition is not quenched with acid.

20 In some aspects of the invention, the system may include a variety of safety mechanisms. Exemplary on-site safety feedback mechanisms for a system are disclosed in further detail in U.S. Patent Publication No. 2009/0208365, which is hereby expressly incorporated by reference including, without limitation, the specification, claims, and abstract, as well as any figures, tables, or drawings
25 thereof. Various safety mechanisms can measure pressure, temperature, difference in pressure, difference in temperature, or a combination thereof and provide a perceptible signal if one or more of these increases above a predetermined level. The level of pressure, temperature, difference in pressure, difference in temperature, or a combination thereof at which safety system provides a perceptible signal can be
30 selected to allow intervention to avoid undesirable or unsafe conditions.

In another aspect of the invention, the system may include a cooling system on the reaction vessels. A cool system may be in combination with a safety

mechanism and/or a measurement device of the system. It may be desirable to have reaction vessels and/or other components of the system under temperature controls. As one skilled in the art will appreciate, exothermic reactions may degrade the reagents according to the generation of the peracid compositions of the invention. In
5 addition, there are various safety considerations for a system to avoid increases in temperature, for example system temperatures in excess of 110°C. In addition, according to an embodiment of the invention, the system has at least one mechanism to cool a reaction vessel and/or other components of the system. Such mechanisms may include, for example, a quenching mode, increased surface area, cooling jacket,
10 venting systems, cold finger, and the like.

In some aspects, the system for making on-site peracid chemistry formulations does not require the use and/or incorporation of any microprocessor control of the system. This is a significant benefit of the system design as it reduces the cost of the ABF system. As opposed to including a controller and/or software
15 platform, the system is configured to prepare a single specific formulation in which the reagent delivery pumps are calibrated to meet the formulation specifications. The pump rate is selected to balance peracid generation against product use.

In some aspects, the system for making on-site peracid chemistry formulations further comprises an optional controller or software platform. The
20 software platform provides a user or system to select a generation mode for a desired peracid formulation for on-site generation. As a result, use of the system for onsite peracid chemistry generation provides significant user flexibility to generate chemistries for particular user-identified purposes. For example, the controller or control software for operation of the system may permit a user or system to select
25 both the peracid formulation and the desired volume of the formulation for on-site generation. In a further aspect, the control software may determine the timing, sequencing and/or selection of feeding raw materials (*e.g.* reagents) into the system, mixing time and total reaction time required for production of the user- or system-selected peracid formulation.

30 According to the invention, the controller may further include a mechanism for manually starting/stopping any of the same functions, including for example a manual switch panel for the same. In addition to manual controls, such as a manual

switch panel, the controller preferably has buttons or other means for selecting particular embodiments according to option displayed by the control software platform. An embodiment of the controller may further include a display screen to assist a user in selecting a generation mode for a desired peracid formulation and
5 any other options for user selection as one skilled in the art will ascertain based upon the description of the invention. Concomitant with the control software are user-friendly instructions for use displayed on the display screen (or the like).

In an aspect of the invention, the control software utilizes a control software algorithm to maximize on-site active chemistry yield and provide safe operating
10 conditions for the reactor vessel(s) of the system. The control software permits user-identified chemistry production to be run in one or multiple reaction vessels and to properly sequence reactions to obtain active chemistries.

Examples of suitable controllers are disclosed herein, in addition various embodiments of those disclosed in U.S. patent application Serial No. 12/108,202,
15 and U.S. Patent No. 7,547,421, both entitled Apparatus and Method for Making Peroxycarboxylic Acid, which are herein incorporated by reference in their entirety.

In another aspect of the invention, the system may include a data output means for
sharing information related to the peroxycarboxylic acid forming compositions
20 and/or peroxycarboxylic acid formulations generated according to the system. For example, an information backbone may be used to both collect and disseminate data from the process of generating the peracid formulations including, for example, composition consumption, dispensing or usage, and additional formulation production-related data. Such data may be generated in real-time and/or provided in
25 a historical log of operational data detectable or storable by a user or system. In an embodiment of the invention a user or system is able to monitor usage and performance, including for example, chemistry dispensing, managing chemistry distribution to various point-of-use applications, communication with system operators to control and monitor chemistry dispensing, allocation and/or formulation
30 and the like. According to an additional embodiment of the invention, a user or system is able to control systems, including program systems, remotely.

According to an aspect of the invention, any system operations suitable for use with the invention may be controlled and/or monitored from a remote location. Remote system operations control and/or monitoring may further include the system updates and/or upgrades. According to an aspect of the invention updates and/or
5 upgrades to system operations may be downloaded remotely. These and other embodiments of data output means, information sharing, remote system operations and the like, which may be adapted for use with the present invention, are further described, for example, in U.S. Patent Nos. 7,292,917, 6,895,307, 6,697,706 and 6,377,868 and U.S. Patent Publication Nos. 2005/0102059, 2005/0065644,
10 2004/0088076, 2003/0195657 and 2003/0195656, which are hereby expressly incorporated by reference including, without limitation, the specification, claims, and abstract, as well as any figures, tables, or drawings thereof.

In another aspect of the invention, the data output for sharing information related to the compositions according to the system may coordinate multiple systems
15 on at a single site. According to this embodiment of the invention, information sharing between the multiple systems may take place using any communications network capable of coupling one or more systems according to the present invention, including for example, using a server computer and a database.

Temperature Controls of Reaction Vessels and/or Manifolds

20 The methods according to the invention may comprise, consist of and/or consist essentially of at least one temperature control for controlling the temperature of a portion of the adjustable biocide formulator or generator system. In one aspect of the invention the temperature controls comprise, consist of and/or consist essentially of adjusting or controlling the temperature of the reaction vessel and/or
25 reaction manifold. In another aspect of the invention the temperature controls comprise, consist of and/or consist essentially of adjusting or controlling the temperature of at least one zone of the ABF system. Adjusting or controlling the temperature of a particular zone of the ABF system, such as the reaction vessel and/or reaction manifold, eliminates variability in temperature caused as a result of
30 environmental factors.

According to an embodiment the temperature of raw starting materials added to an adjustable biocide formulator or generator system may vary as a result of

ambient temperatures. In addition, according to an embodiment the temperature of the adjustable biocide formulator or generator system itself may vary as a result of ambient temperatures. As a result, temperature controls of at least one zone of the system can adjust for changes in ambient temperature and/or adjust the temperature
5 for the peracid reaction to overcome such ambient temperatures. Preferably, the temperature zone adjusts the temperature of the reaction vessel (or the reaction manifold for a continuous system).

In addition, adjusting or controlling the temperature of the reaction vessel and/or reaction manifold eliminates variability in temperature caused by heat
10 generated during the progression of the reaction (e.g. exothermic reaction of forming peracid chemistry). As one skilled in the art will ascertain based on the disclosure of the present invention, the temperature variation can vary significantly based on reaction conditions largely driven by heat of solution caused by dilution of the source of alkalinity (e.g. NaOH (50%)), reaction of that source of alkalinity with
15 hydrogen peroxide and/or neutralization of acidity in the composition. The amount of heat generated through the exothermic reaction is dependent on a number of factors including for example, scale of the reaction and heat transfer properties of the reaction vessel. An exemplary range of temperature variations observed according to the embodiments swings we deal with are typically in the 10-50°F
20 range.

According to an embodiment the control of the reaction vessel and/or reaction manifold temperature may require refrigeration and/or heating. In particular, in one aspect of the temperature control, the temperature is kept cool enough that the chemistry has a reasonable stability window once the peracid has
25 been formed to be dispensed (e.g. maintains within +/- 10 % of its max for at least about 1-10 minutes). The cooling temperature control may be required to decrease the temperature as a result of the exothermic reactions that may degrade the peracid compositions of the invention. In addition, there are various safety considerations for a system to avoid increases in temperature, for example system temperatures in
30 excess of 100°C. In an additional aspect of the temperature control, the temperature is kept warm enough that the reaction can reach the +/- 10% max concentration in a reasonable period of time (e.g. 1-5 minutes or 3-10 minutes).

The means for achieving the temperature control according to these embodiments of the invention may include in one aspect the use of a constant temperature range of the apparatus. According to this embodiment the particular zone of the system to be temperature controlled (e.g. reaction vessel and/or reaction manifold) is put into the constant temperature zone housing a heat source.

5 According to an embodiment of the invention, a continuous or flow through reactor embodied in a reaction manifold is more amenable to temperature control through the use of heat exchangers than the batch-mode ABF systems. This is a result of the temperatures within specific zones of the reaction manifold more easily controlled to

10 achieve complex chemistries that are more difficult to achieve when using a batch-mode ABF system.

Suitable mechanisms for a temperature control mechanism for use in the systems and methods of the invention include, for example, external heating or cooling of a zone (e.g. reaction vessel) and/or the internal heating of the reagents

15 from within the reaction vessel. The temperature control means for increasing the temperature may further include a warm water bath and/or a heating chamber. In an additional aspect of the invention, a temperature control means for increasing the temperature of the ABF system includes the flushing of the system with a hot water source. For example, a water source having a temperature of at least about 37°C

20 (100°F), preferably at least about 48°C (120°F) is flushed through the system periodically (e.g. between batches) to increase the temperature of the system.

Additional exemplary mechanisms for increasing the temperature of the ABF system include the use of heat jacketing of the reaction vessel or a jacketed manifold within the system, which may be achieved through the use of a heated water jacket,

25 for example. In addition, further exemplary mechanisms for increasing the temperature of the ABF system include the use of electro-heating films, heating mantles, heat exchangers and the like. One skilled in the art will ascertain additional means for affording increases in temperature of at least a portion of the adjustable biocide formulator or generator system.

30 In another aspect of the invention, means for achieving the temperature control wherein a decrease in temperature is required may include a cooling system in or around the particular zone of the system

to be temperature controlled (e.g. reaction vessel and/or reaction manifold). For example, it may be desirable to have reaction vessels and/or reaction manifold under refrigeration. Additional mechanisms that may be suitable for use to cool a reaction vessel, reaction manifold and/or other components of the system may include, for
5 example, a quenching mode, increased surface area, cooling jacket, venting systems, cold finger, and the like.

Temperature Controls of Reagents

The methods according to the invention may comprise, consist of and/or consist essentially of at least one means of tempering a reagent used according to the
10 invention. For example, in one aspect a tempered reagent (e.g. water) may be input into a system according to the invention to control the temperature of the adjustable biocide formulator or generator system and/or the generated chemistry.

Suitable mechanisms for tempering a reagent include the preheating of the reagent. For example, a stock solution of a reagent may be housed within a water
15 bath (e.g. warming/cooling) to modify the temperature of the reagent above or below the ambient temperature, as applicable. Thereafter, the temperature adjusted reagent is provided to the ABF system in a preheated manner suitable for use according to the methods of the invention.

Additional exemplary mechanisms for the tempering of a reagent include the
20 use of electric blankets, hot or cold rooms, submersible heaters and the like. One skilled in the art will ascertain additional methods for adjusting the temperature of a reagent according to the invention.

Preferably, a reagent is heated (or cooled to temperature adjust as applicable) to approximately between about 21°C to about 60°C (70-140°F), preferably between
25 about 26°C to about 54°C (80-130°F), and more preferably between about 32°C to about 48°C (90-120°F).

Illustrated Embodiments

According to an embodiment of the invention, as shown in FIG. 1, a user or process controller input, such as a CIP or tunnel washer process controller, selects a
30 peracid formulation desired for on-site generation for a specific cleaning application. The user or process controller input selects both the chemistry formulation and how

much is needed (*i.e.*, gallons use solution) and such input information is loaded into the ABF system. Control software, including a software algorithm, may be used to calculate the timing and sequencing for dosing the raw materials needed for the particular peracid chemistry generation. Raw materials are fed into the reaction
5 vessels of the system under controlled mixture and reaction times.

As shown in the exemplary and non-limiting FIG. 1, the system may employ a variety of measurement devices providing feedback to the system. Measurement devices according to the invention may include devices suitable to measure one or more reaction kinetics or system operations for the generation of peroxycarboxylic
10 acid forming compositions, including for example devices to measure fluorescence, weight, flow, capacitive level, pH, oxidation reduction potential, pressure, temperature and combinations thereof. Such measurement devices may measure the system's feed pumps, reaction vessels, reservoir, outlets, etc. Exemplary measurement devices may include the monitoring and reporting of the temperature
15 of the reaction vessels, temperature of the raw materials in the storage drums, etc. Additional measurement devices may control: the rate of a mixing component, such as an overhead mixer's spin rate; the pressure through a regulator (*i.e.* a regulator affecting the mixing speed in a reaction vessel); reaction vessel volume; pH of raw materials and solutions in reaction and/or reservoir storage vessels; timing of the
20 reaction to generate the peroxycarboxylic acid forming compositions; and the like. As one skilled in the art will ascertain, such regulators, measurement devices, sensors, etc. are well known and are not intended to limit the embodiments of the present invention.

In addition, measurement devices may be used to activate alarms indicating
25 the system and/or methods of generating the of peroxycarboxylic acid forming compositions are outside of desirable ranges; for example, measurement devices may be used to generate out of product alarms (*e.g.* indicating a raw starting material is 'low' or out of product entirely). An exemplary measurement device for such an alarm would measure the availability of a particular raw material (premix or the
30 like) from the volume of such raw material in a drum.

Optionally, for generation of a peroxycarboxylic acid formulation (as opposed to the anion peroxycarboxylic acid forming compositions), the stability of

the reaction intermediates may be enhanced by adding an acid or aqueous acidic solution. The system provides the user or process controller selected peracid formulation for use in a cleaning process, including without limitation, antimicrobial, bleaching, sanitizing and/or antiscaling applications. In addition,
5 various data output and information sharing methods may optionally be employed according to the methods and systems of the invention.

Embodiments of the system 20 are further shown in FIGS. 2 -5. The apparatus of the ABF system 20 may comprise one or more reaction vessels 22 for the generation of the user or process controller selected peracid formulations. As
10 described according to the invention, the ABF system 20 may be configured in single or multiple reaction vessel modes. Notably, a single and/or mixed peracid chemistry can beneficially be produced using either of the embodiments of the invention - single or multiple reaction vessel systems.

FIG. 2 shows a single reaction vessel embodiment of the invention. A single
15 reaction vessel mode is preferred for an individual peracid chemistry. However, single reaction vessel modes may also be used to produce mixed peracid chemistries. To produce a mixed peracid chemistry in a single reactor model, peracids may be produced through the timed addition of more than one sugar ester 24 according to the particular hydrolysis reactions to ensure that the reactions are
20 completed at the same time. According to an embodiment, the raw starting materials 28 (optionally including one or more of the sugar esters 24) may be combined in various premixes as opposed to providing each individual raw starting material 28 from a separate source, as depicted in the exemplary and non-limiting Figures. For clarity the raw starting materials 28 depicted in the figures are limited
25 and/or restricted in any fashion to the arrangement and/or particular number of raw starting material 28 vessels (*e.g.* reagent drum) as shown in the figures. The number of raw starting materials 28 (including the sugar esters 24) used according to the apparatuses and methods of the invention may vary according to the various embodiments of the invention disclosed herein.

30 Sequencing of raw material 28 feeds is critical to producing the correct formulation of peracid-based chemistry. For example, peroxyoctanoic acid (POOA) and peroxyacetic acid (POAA) can be generated through the addition of the sugar

esters 24 sorbitol octanoate and triacetin to a reaction vessel 22, respectively, despite the fact the hydrolysis reactions occur at different rates. The POAA reaction takes place quickly (*e.g.* about 5 minutes) and the POOA reaction takes place at a slower rate (*e.g.* about 15 minutes). Therefore, timing the addition of the sugar ester in
5 excess peroxide at alkaline pH and accurately dosing the amount of sugar ester can be controlled to generate the desired peracid chemistry formulation. In particular, the production of the mixed peracid system using a single reaction vessel requires the adjustment of the reaction time to produce the POAA concomitantly (or in series) with the longer reacting POOA.

10 As a result of the ABF system 20 timing the addition of the sugar esters 24 such that the sugar esters 24 are reacted in the same reaction vessel 22 for predetermined reaction times and then dispensed from an outlet 36 of the reaction vessel 22 or from an outlet 36 of a sump reservoir 34 to a particular cleaning process 38. One skilled in the art shall ascertain based on the disclosure of the present
15 invention that the generation time for mixed peracid systems are dependent upon and vary based on the usage rates of the particular raw starting materials, namely the sugar esters.

In addition to the preferred embodiment of using timed addition of raw materials for measuring the extent of hydrolysis reactions according to the invention,
20 alternative embodiments include reactions based upon volume, weight and/or additional methods to produce a preferred individual peracid chemistry. The ABF system 20 according to the invention may use various methods to measure the extent of a reaction, including for example, temperature rise, oxidation reduction potential and/or pH. The desired peracid systems selected by a user and/or system (including
25 volume of the peracid system) may impact the hydrolysis reactions. However, it is an advantage of the present invention that the ABF system accommodates for such variations and changes.

FIG. 3 shows a multiple reaction vessel embodiment of the invention. Multiple reaction vessels 22 may be utilized for on-site generation of a mixed
30 peracid system. A second reactor vessel 22 may be run sequentially or in parallel. According to the invention, either a user or a control software initially determines the dosage, mix time and sequencing of raw materials 28 (including sugar esters 24)

via feed pump 26 into the reaction vessels 22. The proper sequencing and timing ensures that both perhydrolysis reactions generate reaction intermediates that are completed at the same time. Reaction intermediates are then either combined in a single reaction vessel 22, pumped to a third or additional reaction vessel 22 to mix
5 the reaction intermediates, or pumping to a reservoir 34 for outlet 36 to a cleaning process 38. Alternatively, the reaction intermediates may be dispensed directly from an outlet 36 of one or more of the reaction vessels 22.

For any of the exemplary and non-limiting systems depicted in FIGS. 2-5, the apparatus of the ABF system 20 may include a system of feed pumps 26 fluidly
10 connecting the sugar esters 24 and other raw starting materials 28 to the reaction vessels 22 of the system. The raw starting materials 28 may include any raw material source, including for example sugar esters 24, oxidizing agent, alkalinity source, water, catalysts, water, air, etc. According to one embodiment of the invention, the raw starting materials 28 are depicted as originating from separate
15 containers or sources. However, as the figures depict non-limiting examples of the system, the raw starting materials may be combined, although preferably the reaction catalyst and precursor sugar ester are provided from separate feed pumps 26. According to an embodiment, the raw starting materials 28 (optionally including one or more of the sugar esters 24) may be combined in various premixes as
20 opposed to providing each individual raw starting material 28 from a separate source, as depicted in the exemplary and non-limiting Figures. Feed pumps 26 may feed raw starting materials 28 by various suitable mechanisms known to those skilled in the art. According to an embodiment, feed pumps 26 may feed by tick on a flow meter, wherein the flow meter is calibrated in advance. According to an
25 additional aspect of the invention, a positive displacement pump can be used to count pump strokes for a diaphragm pump or revolutions for a peristaltic pump. Preferably, feed pumps 26 are calibrated prior to use of the system. Raw materials 28 are fed to reaction vessel(s) 22 sequentially or in parallel, as some raw materials 28 maybe fed to the reaction vessel(s) 22 at the same time. Raw materials 28
30 according to the invention include for example, sugar esters 24, oxidizing agent, alkalinity sources, and water. The raw materials 28 are mixed in reaction vessel(s) 22 for a sufficient period of time for perhydrolysis reaction to take place.

In addition, the ABF system 20 may further comprise an acid or aqueous acidic solution source 18 in fluid communication with the reaction vessels 22, reservoir 34 and/or system outlets 36. According to some aspects of the invention, the system 20 measures the extent of the perhydrolysis reaction to determine when
5 to quench the reaction with the acid or aqueous acidic solution source 18 in order to generate a peroxycarboxylic acid formulation. The addition of the acidulant according to the invention increases the solubility of the peroxycarboxylic acid(s). For example, according to the invention, the peroxycarboxylic acid(s) solution may be transported safely without loss of the peracid content. The peroxycarboxylic
10 acid(s) solution may further be diluted to a final use concentration. As one of skill in the art shall ascertain, additional acid may be required for the pH to be in accordance with the certified levels.

According to the invention, certain measurement devices may be employed to determine the extent of the perhydrolysis reaction for dosing of the acid or
15 aqueous acidic solution source 18. Measurement devices can include, for example, time, temperature, oxidation reduction potential, pH, etc. Such devices may measure fluorescence, weight or mass, flow, capacitive level, pH, oxidation reduction potential, pressure, temperature and combinations thereof. Such measurement devices may measure the system's feed pumps, reaction vessels,
20 reservoir, outlets, etc., as disclosed herein.

According to the invention, the raw materials 28 are mixed in reaction vessel(s) 22 for a sufficient period of time for perhydrolysis reaction to take place. Various mechanisms for mixing the raw materials may be employed, including for example, the shape of the reaction vessel (*e.g.* convex shape at the bottom) designed
25 to assist in mixing its contents, employing mixers (*e.g.* impellers for circulation within the reaction vessel), circulation pumps, gravity-driven circulation between vessels, and/or combinations. According to a preferred embodiment of the invention, overhead mixers are preferred for the methods and systems of the invention. In particular, overhead mixers are utilized to drive a mixing element, such as an
30 impeller mixer, within the reaction vessel according to an embodiment of the invention.

Notably, the exemplary ABF system depicted in FIG. 3 showing a multiple reaction vessel embodiment of the invention can further be utilized for on-site generation of a single peracid system. A second reactor vessel 22 may be run sequentially or in parallel for generation of a single peracid system. Such an
5 embodiment is well suited for users wishing to employ the systems according to the invention and having the option for generating both single and mixed peracid systems. For example, a user may select the generation of a single peracid system (when a multi reaction vessel system is employed for on-site generation. According to such an embodiment, the same ABF system, as depicted in FIG. 3 may be used
10 for obtaining both single and mixed peracid systems.

FIG. 4 shows a further embodiment of the invention wherein the ABF system 20 has multiple reaction vessels 22 to allow the in situ acidification to generate a mixed peroxycarboxylic acid formulation. A series of feed pumps 26 fluidly connect the source of raw materials 28 (including sugar esters 24) to the
15 series of reaction vessels 22 of the system 20. The depicted exemplary system of the invention show in FIG. 4 reacts a first sugar ester 24 in a first reaction vessel 22 with certain raw materials 28 added sequentially (*i.e.* an oxidizing agent, and a source of alkalinity). The first reaction vessel can be diluted with water as a further raw material 28. The reaction temperature can be controlled using a tank heater 42. For
20 example, according to an embodiment of the invention wherein the perhydrolysis reactions into two steps (*i.e.* depicted wherein sugar esters 24 are added to separate reaction vessels 22), the overall temperature of the reaction mixture may be controlled and is lower. The reaction can be controlled so as to favor the reaction conditions for formation of each of the percarboxylic acids individually in such an
25 exemplary system. After allowing the reaction mixture to react for a sufficient amount of time in the first reaction vessel 22, the reaction mixture is transferred to a second reaction vessel 22 wherein the second sugar ester 24 is added and allowed to react for a sufficient amount of time. Thereafter an acid or aqueous acidic solution source 18 may be added to the second reaction vessel 22.

30 An exemplary mixed peroxycarboxylic acid system for use of ABF generator of FIG. 4 is a mixed system of POAA/POOA. According to an embodiment the first reaction vessel is used to react esters (*e.g.* glyceryl octanoate) to produce

peroxyoctanoic acid (POOA), using caustic and peroxide. According to an embodiment the caustic and peroxide are blended prior to adding the ester. The reaction vessel is heated slightly above ambient to accelerate production of POOA, preferably between about 32°C to about 49°C (90-100°F).. The second reaction vessel is filled to a sub-maximal volume with water prior to adding the POOA from the first reaction vessel in order to prevent the degradation of the peroxydicarboxylic acid and to decrease the temperature of the reaction mixture. The second sugar ester (*e.g.* triacetin) is introduced into the second reaction vessel following the dilution of the POOA reaction mixture solution. The pH remains high (preferably about > 12.0) in the second reaction vessel and the second ester is reacted to generate POAA. After a sufficient amount of time as passed for the reaction to complete, the addition of an acidulant (*e.g.* acetic acid) lowers the pH to pre-use dilution levels resulting in a solution with increased stability of the peracids (*e.g.* up to 5 days), as well as increased solubility of the POOA of the mixed peroxydicarboxylic acid system.

FIGS. 5 and 9 show expanded views of a controller 50 according to an embodiment of the invention. As depicted, the controller 50 is a part of the ABF system 20 for making on-site peracid chemistry formulations as described by various embodiments herein. The controller 50 may also be described as a software platform or as comprising a software platform. As one skilled in the art will ascertain, the ABF system 20 employing a controller system 50 is not limited to the particular embodiment depicted in FIGS. 5 and 9 (*i.e.* a multiple reaction vessel embodiment of the invention).

In some aspects the controller 50 may include various components, including for example, a display screen 52 to assist a user in selecting the various parameters selectable by a user according to the invention. For example, a user views a display screen 52 to view the options available for a particular generation mode of a desired peracid formulation and any other options for user selection as one skilled in the art will ascertain based upon the description of the invention. Concomitant with the controller and software 50 are user-friendly instructions for use displayed on the display screen 52. In additional aspects, the controller 50 may further include a

means for manually starting/stopping any of the same functions, including for example a manual switch panel 56 for the same. In addition to manual controls depicted as manual switch panels 56 in FIGS. 5 and 9, the controller 50 preferably also comprises means for selecting 54 options displayed for a user to select on the display screen 52. These and other means for a user to select the various embodiments of the invention are encompassed in the various embodiments of the controller 50.

The controller 50 provides a user or system the flexibility and means to select a generation mode for a desired peracid formulation for on-site generation according to the invention. The controller provides significant user flexibility to generate chemistries for particular user-identified purposes, such as selecting the peracid formulation and/or the desired volume of the formulation for on-site generation. The software utilized by the controller 50 may further determine the timing, sequencing and/or selection of feeding raw materials 28 (including sugar esters 24) into the system, mixing time and total reaction time required for production of the user- or system-selected peracid formulation.

In some aspects of the invention, reaction intermediates or peracid formulations may be dosed directly from reaction vessel(s) 22 or a sump reservoir 34 into cleaning process 38 from a system outlet 36.

FIG. 6 shows an embodiment of a reaction manifold 22 for the continuous generation of peracid chemistry. As depicted in a diagram form, one or more peracids can be generated using a reaction manifold(s) 22 as opposed to reaction vessels 22 described herein with respect to FIGS. 2-5. To produce a mixed peracid chemistry in a reaction manifold 22 system 20, peracids may be produced through the timed addition of more than one sugar ester 24 (e.g. a raw starting material 28) according to the particular hydrolysis reactions to ensure that the reactions are completed at the same time. Sequencing of raw material 28 feeds is critical to producing the correct formulation of peracid-based chemistry. For example, peroxyoctanoic acid (POOA) and peroxyacetic acid (POAA) can be generated through the addition of the sugar esters sorbitol octanoate and triacetin 28 to a reaction manifold 22, respectively, despite the fact the hydrolysis reactions occur at different rates. The POAA reaction takes place quickly and the POOA reaction

takes place slower. Timing the addition of the sugar ester in excess peroxide at alkaline pH and accurately dosing the amount of sugar ester can be controlled to generate the desired peracid chemistry formulation. As a result of the ABF system 20 timing the addition of the raw starting materials 28 (e.g. sugar esters 24) such that the sugar esters 24 are reacted in the desired location of the reaction manifold 22 for predetermined reaction times and then dispensed from the reaction vessel 22 to a sump reservoir 34 (may also be referred to as a dilution tank 34) to a cleaning process 38.

In addition to the preferred embodiment of using timed addition of raw starting materials 28 for measuring the extent of hydrolysis reactions according to the invention, alternative embodiments include reactions based upon volume, weight and/or additional methods to produce a preferred for individual peracid chemistry. The ABF system 20 according to the invention may use various methods to measure the extent of a reaction, including for example, temperature rise, oxidation reduction potential and/or pH. The desired peracid systems selected by a user and/or system (including volume of the peracid system) may impact the hydrolysis reactions. However, it is an advantage of the present invention that the ABF system accommodates for such variations and changes.

As shown in FIG. 2 the raw starting materials 28 (including sugar esters 24) are added to a system via feed pumps 26 into the reaction manifold 22. The systems may optionally include mixers or means for mixing the raw starting materials 28 as they are added into the reaction manifold for dilution, perhydrolysis, etc. The proper sequencing and timing ensures that both perhydrolysis reactions generate reaction intermediates that are completed at the same time. For any of the exemplary and non-limiting systems depicted in the figures, the apparatus of the ABF system 20 may include a system of feed pumps 26 fluidly connecting the sugar esters 24 and other raw starting materials 28 to the reaction vessels 22 of the system. The raw starting materials 28 may include any raw material source, including for example sugar esters 24, oxidizing agent, alkalinity source, water, catalysts, water, air, etc. According to the embodiment of FIG. 2, the raw starting materials 28 are depicted as originating from separate containers or sources. However, as the figures depict non-limiting examples of the system, the raw starting materials may be combined into

various premix formulations to reduce the number of raw starting materials individually combined into a system, although preferably the reaction catalyst and precursor sugar ester are provided from separate feed pumps 26.

Feed pumps 26 may feed raw starting materials 28 by various suitable mechanisms known to those skilled in the art. According to an embodiment, feed pumps 26 may feed by tick on a flow meter, wherein the flow meter is calibrated in advance. According to an additional aspect of the invention, a positive displacement pump can be used to count pump strokes for a diaphragm pump or revolutions for a peristaltic pump. Preferably, feed pumps 26 are calibrated prior to use of the system. Raw materials 28 are fed to the reaction manifold 22 sequentially or in parallel, as some raw materials 28 maybe fed to the reaction vessel(s) 22 at the same time. Raw materials 28 according to the invention include for example, sugar esters 24, oxidizing agent, alkalinity sources, and water. The raw materials 28 are mixed in reaction vessel(s) 22 for a sufficient period of time for perhydrolysis reaction to take place.

In addition, the ABF system 20 may further comprise an acid or aqueous acidic solution source 18 in fluid communication with the reaction manifold 22, reservoir 34 and/or system outlets 36. According to some aspects of the invention, the system 20 measures the extent of the perhydrolysis reaction to determine when to quench the reaction with the acid or aqueous acidic solution source 18 in order to generate a peroxycarboxylic acid formulation. The addition of the acidulant according to the invention increases the solubility of the peroxycarboxylic acid(s). For example, according to the invention, the peroxycarboxylic acid(s) solution may be transported safely without loss of the peracid content. The peroxycarboxylic acid(s) solution may further be diluted to a final use concentration. As one of skill in the art shall ascertain, additional acid may be required for the pH to be in accordance with the certified levels.

FIG. 7 shows a further depiction of an embodiment of the invention. An injection manifold 50 using a pneumatic supply is depicted wherein raw starting materials 28 (according to any of the embodiments described herein, including for example premix formulations) are added to a system 20 via feed pumps 26 into the reaction manifold 22. The systems may optionally include mixers or means for

mixing the raw starting materials 28 as they are added into the reaction manifold 22. Alternatively, the continuous flushing of the reaction manifold 22 with the raw starting materials 28 according to the invention may provide suitable mixing for the perhydrolysis reaction to occur. As depicted in FIG. 7, a pressure gauge and/or
5 source of compressed air 38 may be incorporated into the system. (Include description of significance).

The system 20 of FIG. 7 depicts a non-limiting embodiment of the reaction manifold 22 according to the invention. In particular, a vertically spiraled, helical track is implemented as the reaction manifold. Beneficially, this embodiment assists
10 in removing gas that may be generated from the system (and may optionally further include the use of permeable membranes to further assist in the elimination of gas from the system). The system 20 further depicts the flow of raw starting materials 28 added via an injection manifold 50 through the reaction manifold 22 and provided to a sump reservoir or dilution tank 34. The peracid chemistry may be diluted with a
15 water source 28 and/or acidified with an acid source 18 within the sump reservoir or dilution tank 34 and is then stored until transfer for use in a cleaning process 38.

FIG. 8A shows a further embodiment of the invention wherein the ABF system 20 uses various injection manifolds 50 for the timed addition of raw starting materials 28. According to the particular depicted embodiment, a source of
20 compressed air 38 is used in the first injection manifold 50 to aid in the mixing of the chemistry within the reaction manifold 22. Thereafter a second injection manifold 50 provides additional raw starting materials 28 prior to mixing the chemistry within a further portion of the reaction manifold 22. Thereafter the chemistry is provided FIG. 8B shows a further embodiment wherein particular raw
25 starting materials are selected for the timely addition to the system 20 to promote the efficiency of the chemistry production. In particular, NaOH 12 and water 14 are provided at a first injection manifold 50 to the reaction manifold 22 of the system. Thereafter, the diluted caustic is combined with an ester premix 16 (or its individual components shown as an ester 24 and a peroxide source 10) and continues to move
30 through the reaction manifold 20 for the perhydrolysis reaction according to the invention. The chemistry is then provided to a sump reservoir or dilution tank 34

where the chemistry may be diluted with water 14 and/or acidified with an acid source 18, where it is then stored until transfer for use in a cleaning process 38.

FIGS. 10A and 10B show diagrams of an embodiment of an adjustable biocide formulator apparatus according to the invention, including description of the dosing of raw starting materials (e.g. reagents) for the generation of peracid chemistries according to the invention. In particular, FIG. 10A shows a process flow of methods of making the peracid chemistry using the apparatus according to the invention. As set forth, methods of the invention include the steps of peracid generation, a period of reaction holding time followed by evacuation of the line, dilution with water of the concentrated chemistry and optionally acidification.

FIG. 10B further shows a non-limiting example of a method of peracid chemistry according to FIG. 10A. In the non-limiting example peracid generation includes the injection of raw starting materials (e.g. reagents). In particular, the injection of NaOH 12 and water 14 are combined in injection manifold 21. The injection manifold is not limited according to a particular structure or apparatus. According to a preferred embodiment, the caustic is diluted to a concentration of less than or equal to about 20% by weight. The NaOH 12 and water 14 are preferably homogenized or mixed by passing through a mixer 35. Thereafter, the ester premix or ester and peroxide 16 are injected into another injection manifold 21 of the system. According to this aspect of the invention the ester premix or ester and peroxide are added to the dilute NaOH for improved chemistry generation. The ester premix or its individual components 16 are homogenized or mixed 35 with the caustic stream. Following the mixing, the reagents are held for the reaction to go to completion within a reaction manifold 22. Notably, the holding step can occur directly in a dilution tank 34 or optionally in an intermediate reaction manifold 22. Following the reaction hold time the reaction manifold 22 is purged with water then air into a dilution vessel 34 (e.g. line evacuation). Then water 14 is used for the dilution step within the dilution tank 34 to dilute the concentrated chemistry. In a further aspect the diluted chemistry can be acidified using an acid or aqueous acid solution 18 within the dilution vessel 34 (or optionally within the reaction manifold 22 – not depicted in the figure). Upon completion of the peracid generation as

depicted in FIGS. 10A-B a water source 14 may be used to flush the system at a high flow rate.

Apparatus Dosing

The apparatus of the ABF system overcomes the raw material feed design
5 challenge of accurately dosing raw materials. According to the invention, liquid based raw materials must be dosed into reaction vessel(s) quickly. For example, according to an embodiment of the invention, the sugar ester is the limiting reaction ingredient and requires accurate dispensing of the raw material. An example of a suitable sugar ester is sorbital octanoate and/or glyceryl octanoate, which are viscous
10 liquids that are difficult to accurately measure. As a result, pump selection is critical and accommodating pump characteristics with software is a critical embodiment of the ABF system.

The dispensing precision required to prepare small batch sizes is more critical than larger batches, as a result of the dispensing error becoming a larger
15 percentage of the dispensed peracid chemistries. As a result, the apparatus of the ABF system provides feed pumps to reduce the presence of air bubbles in the delivery line altering the amount of sugar ester chemistry dispensed and reducing the overall yield of the reaction. In addition to providing suitable feed pumps, the concentration of the sugar ester may be diluted to increase dosing accuracy. Such
20 methods improve the dosing accuracy and decrease variations in volumetric flow of reagents according to the invention. In addition to the reduction of air bubbles in a delivery line, the dispensing precision according to the invention delivers the reagents at a constant flow rate over long durations of time, thereby reducing and/or eliminating the need for recalibration of the apparatus.

25 Although the dispensing precision required to prepare continuous amounts of the chemistry is less critical than with small batch preparation. Regardless, the apparatus of the ABF system provides feed pumps to reduce the presence of air bubbles in the delivery line to ensure accurate dosing of raw starting materials, including sugar esters, resulting in decreased variation in volumetric flow of
30 reagents. In addition to the reduction of air bubbles in a delivery line, the dispensing precision according to the invention delivers the reagents at a constant flow rate over

long durations of time, thereby reducing and/or eliminating the need for recalibration of the apparatus.

According to an alternative embodiment of the invention, a viscosity modifier may be added to the sugar ester. A viscosity modifier is a further example
5 of a suitable raw material 28 according to the invention. Viscosity modifiers according to the invention may be used to adjust the rheology of a reagent in order to reduce the viscosity to make a raw material more suitable for use in the apparatus and system according to the invention, namely rendering the raw material significantly easier to pump.

10 An additional embodiment of the invention is to provide the apparatus of the ABF system having a vertical alignment of equipment to manage drips and siphoning. In addition, self checking pumps and foot valves may be used to manage air bubbles. Still further, speed control boards used in ware washing applications for rinse aid delivery may be used to slow down the pumping rate of the reaction
15 limiting sugar esters to improve accuracy. A skilled artisan will appreciate, based on the disclosure of the present invention, additional dosing modifications of the ABF system encompassed within the scope of the present invention.

Apparatus Rinsing

Rinsing of the ABF system has an impact on yield. According to an
20 embodiment of the invention, adequate rinsing of the reactor vessel(s) and feed pump lines is necessary. According to a preferred embodiment of the invention, the control software of the ABF system may be used to establish a process for system rinsing both reactor vessel(s) and feed pump lines. Remaining water after rinsing or flushing does not have a negative impact on the system. Water remaining in the
25 mixing manifold imparts a dilution factor for which the dilution factor can be accommodated in the formulation. However, reaction intermediates must be rinsed from the system, as any reacted chemistry not flushed impacts the yield of a subsequent batch. This is a result of residual reaction intermediates in the system imparting unknown actives concentration due to the instability of the product at high
30 pH over time. In addition, according to an embodiment an air-purge may be further employed after rinsing of the apparatus according to the invention, which as one

skilled in the art will appreciate effectively removes nearly all liquid content from the apparatus after a water rinse.

Preferably, the ABF system, including the reaction vessels, are cleaned between batches of peroxycarboxylic acid forming compositions. According to an
5 embodiment of the invention, the system is rinsed (*e.g.* feed pump lines flushed) with warm/hot water between batches, and/or at regularly scheduled intervals to comply with regulatory requirements (*e.g.* sanitizing regulations), as one skilled in the art shall ascertain.

Compositions

10 The embodiments of the invention are suitable for generating the peroxycarboxylic acid chemistries (as well as the anion peroxycarboxylic acid forming compositions) which are disclosed in further detail in the related U.S. patent application Serial Nos. 61/427,965, _____ and _____ (Attorney Docket
Numbers 2757USP1, 2757USU1 and 2757USU2), entitled In Situ Generation of
15 Peroxycarboxylic Acids at Alkaline pH and Methods of Use Thereof, which are herein incorporated by reference in its entirety. In addition to the chemistries generated, these applications incorporated by reference further disclose the particular raw starting materials (*e.g.* reagents) suitable for use in the ABF systems according to the invention to generate the particular chemistries.

20 In some embodiments, the system according to the present invention produces peroxycarboxylic acid forming compositions or peroxycarboxylic acid compositions for use in a variety of cleaning applications. The compositions have enhanced stability. According to an embodiment of the invention, the peroxycarboxylic acid forming compositions are stable for up to 24 hours providing
25 suitable stability for on-site generation and usage for a variety of cleaning applications. According to a further embodiment, the peroxycarboxylic acid compositions are stable for up to at about 7 to 10 days.

In some aspects, the present disclosure relates to peroxycarboxylic acid forming compositions. That is, the compositions are capable of generating
30 peroxycarboxylic acids in situ, in a non-equilibrium reaction. Surprisingly, it has been found that the optimum pH for the generation of peroxycarboxylic acid compositions is greater than about 12, or pH greater than about 13. It has also been

found that mixed peroxycarboxylic acid compositions, viz. compositions that form two or more peroxycarboxylic acids, can be generated in situ in accordance with the methods disclosed herein. Peroxycarboxylic (or percarboxylic) acids generally have the formula $R(CO_3H)_n$, where, for example, R is an alkyl, aryl alkyl, cycloalkyl, aromatic, or heterocyclic group, and n is one, two, or three, and named by prefixing the parent acid with peroxy. The R group can be saturated or unsaturated as well as substituted or unsubstituted.

In an embodiment of the invention the peroxycarboxylic acid forming compositions comprise individual reagents combined according to the invention. These reagents are described herein individually along and include at least one ester of a polyhydric alcohol and a C1 to C18 carboxylic acid, an oxidizing agent, a source of alkalinity, solvents, and other functional groups. An acidulant is also described herein as a reagent to be added to the compositions after the formation of the percarboxylic acid(s). Alternatively, as described herein, there may be benefits to providing the reagents in various premix formulations to decrease the number of reagents and/or increase the simplicity of the invention. Each of these embodiments are described in further detail herein.

Esters

In some aspects, the compositions include an ester of a polyhydric alcohol and a C1 to C18 carboxylic acid. According to an embodiment, the polyhydric alcohol may also include a sugar alcohol. The compositions can also include more than one or a mixture of esters of a polyhydric alcohol and a C1 to C18 carboxylic acid. For example, in some embodiments, the compositions include two, three or four esters. When more than one ester is present, the esters can be different. For example, in some embodiments, the compositions can include a first ester of a polyhydric alcohol and a C1 to C4 carboxylic acid, and a second ester of a polyhydric alcohol and a C5 to C11 carboxylic acid. For further example, in some embodiments, the compositions can include a first ester of a polyhydric alcohol and a C1 to C18 carboxylic acid in a mono, di or tri-formation, and a second ester of a polyhydric alcohol and a C1 to C18 carboxylic acid in a mono, di or tri-formation. One skilled in the art will appreciate the various combinations of esters that can be used for the compositions according to the invention.

An example of a suitable ester for use according to the invention is glycerol octanoate. Glycerol octanoate has multiple ester components and others, including glycerol mono-octanoate, glycerol di-octanoate, glycerol tri-octanoate and others (glycerin, fatty acid, water). An estimated component percentage of each is

5 approximated at about 39.6% glycerol mono-octanoate, 24.5% glycerol di-octanoate, 1.42% glycerol tri-octanoate and 34.5% of the others (glycerin, fatty acid, water).

The use of various forms of an ester (e.g. mono, di and/or tri-formations) to comprise a mixture of esters will impact the peracid yield of a particular composition according to the invention. For example, the various forms of the ester

10 will have different kinetics in generating the peracids according to the methods of the invention. For example, in one aspect, a mono-octanoate glycerol ester is faster in generating peracid than the di- or tri-octanoate glycerol esters. In addition, the selection of the various forms of an ester will be further impacted by the water solubility of the compositions and whether any additional ingredients are combined

15 to affect solubility (e.g. solvents) that would favor the use of less soluble ester forms (e.g. tri-formations). Accordingly, one skilled in the art of reaction kinetics will ascertain the benefits of using various combinations or mixtures of esters according to the compositions and methods of the invention.

The esters for use in the present invention include esters of polyhydric

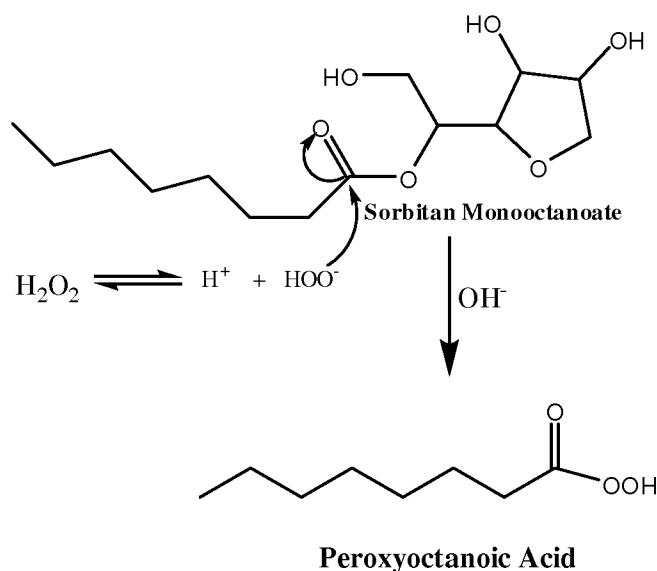
20 alcohols with carboxylic acid based leaving groups. A variety of carboxylic acids can be included. Carboxylic acids generally have the formula $R(\text{COOH})_n$, where, for example, R is an alkyl, aryl alkyl, cycloalkyl, aromatic, or heterocyclic group, and n is one, two, or three. In some embodiments, the carboxylic acid leaving group is a C₅ to C₁₁ carboxylic acid. In some embodiments, the carboxylic acid leaving

25 group is a C₁ to C₄ carboxylic acid. In other embodiments, the compositions include two esters of polyhydric alcohols, each ester having a different carboxylic acid leaving group. For example, the compositions can include a polyhydric alcohol ester with a C₁ to C₄ carboxylic acid leaving group, and also include a polyhydric alcohol ester with a C₅ to C₁₁ carboxylic acid leaving group.

30 Examples of suitable carboxylic acids include, but are not limited to, formic, acetic, propionic, butanoic, pentanoic, hexanoic, heptanoic, octanoic, nonanoic, decanoic, undecanoic, dodecanoic, as well as their branched isomers, lactic, maleic,

ascorbic, citric, hydroxyacetic, neopentanoic, neoheptanoic, neodecanoic, oxalic, malonic, succinic, glutaric, adipic, pimelic subric acid, and mixtures thereof.

Without wishing to be bound by any particular theory, it is thought that the esters included in the compositions undergo a perhydrolysis reaction, thereby
 5 forming the peroxycarboxylic composition. An exemplary perhydrolysis reaction in accordance with the present disclosure is illustrated below:



As can be seen from this illustration, it is thought the oxidizing agent, H_2O_2 , perhydrolyzes the ester bond, thereby forming the percarboxylic acid corresponding
 10 to the cleaved carboxylic acid group. In contrast to an acid catalyzed equilibrium reaction, the reaction is stoichiometric, i.e. no excess amounts of the reactants are required for the reaction. The kinetics of the reaction are pH dependent, and the reaction can reach the maximum yield in the order of minutes. Esters suitable for use include, but are not limited to, mono-octanoic glyceride, dioctanoic glyceride,
 15 tri-octanoic glyceride, polyglycerol octanoate, sorbitan mono-octanoate, sorbitan dioctanoate, sorbitan tri-octanoate, laurate sucroside and mixtures and derivatives thereof.

The compositions include the esters in an amount sufficient to generate the desired amount of percarboxylic acid. In some embodiments, the compositions
 20 include about 0.01 wt-% to about 95 wt-% of the ester, about 0.1 wt-% to about 50 wt-% of the ester, or about 1 wt-% to about 10 wt-% of the ester. In some

embodiments, more than one ester is present in the compositions. Each ester can be present in the compositions at the above stated weight percents.

Unlike conventional acid catalyzed equilibrium peroxydicarboxylic acid forming compositions, the compositions of the present invention can be formed using a non-equilibrium perhydrolysis reaction. Thus, an excess amount of the starting reagents is not needed. Accordingly, after formation of the peroxydicarboxylic acid, the compositions contain less dicarboxylic acid and more peroxydicarboxylic acid than an equivalent equilibrium reaction. In some embodiments, the compositions contain about 1 part perdicarboxylic acid for every about 1 part dicarboxylic acid after perhydrolysis, or about 6 part perdicarboxylic acid for every about 1 part dicarboxylic acid after perhydrolysis. In some embodiments, the compositions are free of or substantially free of dicarboxylic acids after the perhydrolysis reaction.

Alkalinity Source

The compositions also include a source of alkalinity. The source of alkalinity can include, but is not limited to, an alkaline metal hydroxide, an alkaline earth metal hydroxide, an alkali metal silicate, an alkali metal carbonate, borates and mixtures thereof. Suitable alkaline metal hydroxides include, but are not limited to, sodium hydroxide, potassium hydroxide and mixtures thereof. Suitable alkaline earth metal hydroxides include, but are not limited to, magnesium hydroxide, calcium hydroxide and mixtures and derivatives thereof. Suitable alkali metal silicates include but are not limited to, sodium silicate and derivatives thereof. In other embodiments, an alkali metal carbonate can be used as a source of alkalinity. For example, in some embodiments, sodium carbonate, sodium bicarbonate or mixtures and derivatives thereof can be used.

The source of alkalinity can be present in the compositions in an amount sufficient to provide the desired pH. In some embodiments, the compositions have a pH greater than about 12, greater than about 12.5, or greater than about 13. In some embodiments, the alkaline source is present in the composition from about 0.001 wt-% to about 50 wt-%, from about 1wt-% to about 30wt-%, or about 10wt-% to about 25 wt-%. In some embodiments, the alkaline source is present at from about 25 wt-

% to about 50 wt-% of the composition. It is to be understood that all ranges and values between these ranges and values are encompassed by the present disclosure.

Oxidizing Agent

The compositions also include an oxidizing agent. The oxidizing agent may include a peroxide source. Oxidizing agents suitable for use with the compositions include the following types of compounds or sources of these compounds, or alkali metal salts including these types of compounds, or forming an adduct therewith: hydrogen peroxide, urea-hydrogen peroxide complexes or hydrogen peroxide donors of: group 1 (IA) oxidizing agents, for example lithium peroxide, sodium peroxide; group 2 (IIA) oxidizing agents, for example magnesium peroxide, calcium peroxide, strontium peroxide, barium peroxide; group 12 (IIB) oxidizing agents, for example zinc peroxide; group 13 (IIIA) oxidizing agents, for example boron compounds, such as perborates, for example sodium perborate hexahydrate of the formula $\text{Na}_2[\text{B}_2(\text{O}_2)_2(\text{OH})_4] \cdot 6\text{H}_2\text{O}$ (also called sodium perborate tetrahydrate); sodium peroxyborate tetrahydrate of the formula $\text{Na}_2\text{B}_2(\text{O}_2)_2[(\text{OH})_4] \cdot 4\text{H}_2\text{O}$ (also called sodium perborate trihydrate); sodium peroxyborate of the formula $\text{Na}_2[\text{B}_2(\text{O}_2)_2(\text{OH})_4]$ (also called sodium perborate monohydrate); group 14 (IVA) oxidizing agents, for example persilicates and peroxycarbonates, which are also called percarbonates, such as persilicates or peroxycarbonates of alkali metals; group 15 (VA) oxidizing agents, for example peroxyntous acid and its salts; peroxyphosphoric acids and their salts, for example, perphosphates; group 16 (VIA) oxidizing agents, for example peroxydisulfuric acids and their salts, such as peroxydisulfuric and peroxydisulfuric acids, and their salts, such as persulfates, for example, sodium persulfate; and group VIIa oxidizing agents such as sodium periodate, potassium perchlorate. Other active inorganic oxygen compounds can include transition metal peroxides; and other such peroxygen compounds, and mixtures thereof.

In some embodiments, the compositions of the present invention employ one or more of the inorganic oxidizing agents listed above. Suitable inorganic oxidizing agents include ozone, hydrogen peroxide, hydrogen peroxide adduct, group IIIA oxidizing agent, or hydrogen peroxide donors of group VIA oxidizing agent, group VA oxidizing agent, group VIIA oxidizing agent, or mixtures thereof. Suitable

examples of such inorganic oxidizing agents include percarbonate, perborate, persulfate, perphosphate, persilicate, or mixtures thereof.

In some embodiments, the oxidizing agent includes hydrogen peroxide, or a source or donor of hydrogen peroxide. In other embodiments, the oxidizing agent
5 includes a peroxide source selected from a percarbonate, a perborate urea hydrogen peroxide, PVP-peroxides and mixtures thereof.

The compositions may contain an effective amount of an oxidizing agent. In some embodiments, the compositions include about 0.001 wt-% to about 60 wt-% of the oxidizing agent, or about 1 wt-% to about 25 wt-% of the oxidizing agent. In
10 some embodiments, the compositions include about 30 wt-% to about 50 wt-% of the oxidizing agent. It is to be understood that all ranges and values between these ranges and values are encompassed by the present invention.

Solvent

In some embodiments, the compositions of the invention further include a
15 solvent. In some embodiments, the solvent is water. The water may be provided by the use of aqueous reagents, viz. oxidizing agent, alkalinity source. In other embodiments, an additional amount of water is added to the compositions. The compositions may be free of or substantially free of any added water. A non-aqueous solvent may also be used in the compositions. For example, in some
20 embodiments, an alcohol is included as a solvent in the compositions.

The compositions may include an effective amount of solvent. In some embodiments, the compositions may include about 10 wt-% to about 99 wt-% of a solvent, or about 20 wt % to about 80 wt-% of a solvent. In other embodiments, the compositions may include more than about 30 wt-%, more than about 50 wt-%,
25 more than about 60 wt-% or more than 70% of a solvent. It is to be understood that all values and ranges between these values and ranges are encompassed by the present invention.

Eliminated Functional Ingredients

Unlike conventional equilibrium based peroxycarboxylic acid compositions,
30 the compositions disclosed herein are formed from a non-equilibrium reaction. Further, the composition disclosed herein can be used immediately after generation. Thus, many of the additional ingredients required in equilibrium based compositions

do not need to be included in the present compositions. In some embodiments stabilizing agents are preferred for certain compositions according to the invention and provide benefits. However, beneficially, the use of non-equilibrium chemistry according to the present invention optionally provides that the compositions can be
5 free of, or substantially free of a stabilizing agent.

Stabilizing agents are commonly added to equilibrium peroxycarboxylic acid compositions to stabilize the peracid and hydrogen peroxide and prevent the decomposition of these constituents within the compositions. Various embodiments of the invention do not require the use of at least one or more of such stabilizing
10 agents. Examples of stabilizing agents may include for example, surfactants, couplers, hydrotropes, acid catalysts and the like that are conventionally used in equilibrium peracid compositions to stabilize and improve shelf life of the composition.

Further examples of stabilizing agents include, for example, chelating agents
15 or sequestrants. Such sequestrants include, but are not limited to, organic chelating compounds that sequester metal ions in solution, particularly transition metal ions. Such sequestrants include organic amino- or hydroxy-polyphosphonic acid complexing agents (either in acid or soluble salt forms), carboxylic acids (e.g., polymeric polycarboxylate), hydroxycarboxylic acids, aminocarboxylic acids, or
20 heterocyclic carboxylic acids, e.g., pyridine-2,6-dicarboxylic acid (dipicolinic acid). Dipicolinic acid, 1-hydroxy ethylidene-1,1-diphosphonic acid ($\text{CH}_3\text{C}(\text{PO}_3\text{H}_2)_2\text{OH}$) (HEDP) are further example of stabilizing agents.

Additional examples of stabilizing agents commonly used in equilibrium chemistry to stabilize the peracid and hydrogen peroxide and/or prevent the
25 premature oxidation of the composition include phosphonic acid or phosphonate salt. Phosphonic acids and phosphonate salts include HEDP; ethylenediamine tetrakis methylenephosphonic acid (EDTMP); diethylenetriamine pentakis methylenephosphonic acid (DTPMP); cyclohexane-1,2-tetramethylene phosphonic acid; amino[tri(methylene phosphonic acid)]; (ethylene diamine[tetra methylene-
30 phosphonic acid)]; 2-phosphene butane-1,2,4-tricarboxylic acid; or salts thereof, such as the alkali metal salts, ammonium salts, or alkylol amine salts, such as mono, di, or tetra-ethanolamine salts; picolinic, dipicolinic acid or mixtures thereof.

In some embodiments, organic phosphonates, e.g., HEDP are well known as used stabilizing agents.

Exemplary commercially available food additive chelating agents include phosphonates sold under the trade name DEQUEST® including, for example, 1-
5 hydroxyethylidene-1,1-diphosphonic acid, available from Monsanto Industrial Chemicals Co., St. Louis, MO, as DEQUEST® 2010; amino(tri(methylenephosphonic acid)), (N[CH₂PO₃H₂]₃), available from Monsanto as DEQUEST® 2000; ethylenediamine[tetra(methylenephosphonic acid)] available from Monsanto as DEQUEST® 2041; and 2-phosphonobutane-1,2,4-tricarboxylic
10 acid available from Mobay Chemical Corporation, Inorganic Chemicals Division, Pittsburgh, PA, as Bayhibit AM. Further exemplary sequestrant can be or include aminocarboxylic acid type sequestrant. Suitable aminocarboxylic acid type sequestrants include the acids or alkali metal salts thereof, e.g., amino acetates and salts thereof. Suitable aminocarboxylates include N-hydroxyethylaminodiacetic
15 acid; hydroxyethylenediaminetetraacetic acid, nitrilotriacetic acid (NTA); ethylenediaminetetraacetic acid (EDTA); N-hydroxyethyl-ethylenediaminetriacetic acid (HEDTA); diethylenetriaminepentaacetic acid (DTPA); and alanine-N,N-diacetic acid; and the like; and mixtures thereof. Still further sequestrants include polycarboxylates, including, for example, polyacrylic acid, maleic/olefin copolymer,
20 acrylic/maleic copolymer, polymethacrylic acid, acrylic acid-methacrylic acid copolymers, hydrolyzed polyacrylamide, hydrolyzed polymethacrylamide, hydrolyzed polyamide-methacrylamide copolymers, hydrolyzed polyacrylonitrile, hydrolyzed polymethacrylonitrile, hydrolyzed acrylonitrile-methacrylonitrile copolymers, polymaleic acid, polyfumaric acid, copolymers of acrylic and itaconic
25 acid, phosphino polycarboxylate, acid or salt forms thereof, mixtures thereof, and the like.

Further, unlike conventional equilibrium based peroxycarboxylic acid compositions, the present compositions can also be free of, or substantially free of surfactants. This is especially advantageous for compositions incorporating C5 to
30 C18 peroxycarboxylic acids. That is, under perhydrolysis conditions, the C5-C18 peroxycarboxylic acid anions generated are water soluble. If the anions (e.g. peroxycarboxylic acid-forming compositions) are acidified for end use applications,

the concentrations of peroxydicarboxylic acids are below the water solubility limit of the peroxydicarboxylic acids. Thus, couplers are not needed to couple the peroxydicarboxylic acids in solution.

Additional Functional Ingredients

5 The compositions may also include additional functional ingredients. Additional functional ingredients suitable for use in the present compositions include, but are not limited to, acidulants, hydrotropes, dispersants, antimicrobial agents, optical tracers, solidification agent, aesthetic enhancing agent (i.e., colorant (e.g., pigment), odorant, or perfume), among any number of constituents which can
10 be added to the composition. For example, suitable functional ingredients for various embodiments of the invention are hydrotropes, which may be desired for producing clear compositions or dispersants which are more efficient in producing homogeneous dispersions. Such adjuvants can be preformulated with the present compositions or added to the compositions after formation, but prior to use. The
15 compositions can also contain any number of other constituents as necessitated by the application, which are known and which can facilitate the activity of the present compositions.

Acidulant

 In an embodiment, the present compositions can include an acidulant. The
20 acidulant can be added to the compositions after the formation of the percarboxylic acid. That is, an acidulant can be added to the peroxydicarboxylic acid concentrate to form an acidified use solution. The acidulant can be effective to form a use composition with pH of about 1 or less. The acidulant can be effective to form a use composition with pH of about 8, about 8 or less, about 7, about 7 or less, about 6,
25 about 6 or less, about 5, about 5 or less, or the like. In some embodiments, the acidulant is present at an amount effective to form a use solution with a pH of about 6 to about 8, about 1 to about 8, or about 1 to about 5. In a further embodiment, the acidulant may be added to a semi-diluted reaction solution to produce meta-stable peracid composition.

30 Any suitable acid can be included in the compositions as an acidulant. In an embodiment the acidulant is an acid or an aqueous acidic solution. In an embodiment, the acidulant includes an inorganic acid. In some embodiments, the

acidulant is a strong mineral acid. Suitable inorganic acids include, but are not limited to, sulfuric acid, sodium bisulfate, phosphoric acid, nitric acid, hydrochloric acid. In some embodiments, the acidulant includes an organic acid. Suitable organic acids include, but are not limited to, methane sulfonic acid, ethane sulfonic acid, propane sulfonic acid, butane sulfonic acid, xylene sulfonic acid, cumene sulfonic acid, benzene sulfonic acid, formic acid, acetic acid, mono, di, or tri-halocarboxylic acids, picolinic acid, dipicolinic acid, and mixtures thereof. In some embodiments, the compositions of the present invention are free or substantially free of a phosphorous based acid.

10 In an embodiment, the acidulant includes a carboxylic acid with pK_a less than 5. Suitable carboxylic acids with pK_a less than 5 include acetic acid, hydroxyacetic acid, hydroxypropionic acid, other hydroxycarboxylic acids, mixtures thereof, or the like. Such an acidulant is present at a concentration where it does not act as a solubilizer. In some embodiments, the compositions are free of, or
15 substantially free of a carboxylic acid.

 In certain embodiments, the present composition includes about 0.001 to about 50 wt-% acidulant, about 0.001 to about 30 wt-% acidulant, about 1 to about 50 wt-% acidulant, about 1 to about 30 wt-% acidulant, about 2 to about 40 wt-% acidulant, about 2 to about 10 wt-% acidulant, about 3 to about 40 wt-% acidulant,
20 about 5 to about 40 wt-% acidulant, about 5 to about 25 wt-% acidulant, about 10 to about 40 wt-% acidulant, about 10 to about 30 wt-% acidulant, about 15 to about 35 wt-% acidulant, about 15 to about 30 wt-% acidulant, or about 40 to about 60 wt-% acidulant. The composition can include any of these ranges or amounts not modified by about.

25 *Premix Formulations*

 In an embodiment, the reagents described herein (e.g. at least one ester of a polyhydric alcohol and a carboxylic acid, source of alkalinity, oxidizing agent) may be combined into various premix formulations to reduce the number of raw starting materials required for the methods and compositions and further simplify the
30 methods of the invention. According to such an embodiment the providing of premix formulations ensures consistent and stable delivery of reagents.

Premix formulations suitable for use according to the invention may comprise, consist of and/or consist essentially of at least one ester, an oxidizing agent and mixtures thereof. Premix formulations suitable for use according to the invention may comprise, consist of and/or consist essentially of at least one ester, an
5 oxidizing agent, a solvent and mixtures thereof. Premix formulations suitable for use according to the invention may also comprise, consist of and/or consist essentially of at least one ester, an oxidizing agent, water, solvents, dispersing agents, and mixtures thereof.

As one skilled in the art will ascertain the use of premixes employs
10 additional function ingredients for purpose of stabilizing the premix concentrate for use in the compositions and methods according to the invention. For example, hydrotropes, dispersing agents and/or other solvents may be desirable for maintaining the solubility and stability of a particular concentrated premix. The use of any couplers or dispersing agent (such as a surfactant) within a premix
15 formulation is distinct from the use of surfactants in the conventional generation and storage of peracid chemistries, wherein couplers are critical to establishing and maintaining a stable, clear solution of the generated peracid chemistry.

According to the invention, the use of dispersing agents alone within a concentrated premix formulation does not stabilize the premix composition. Rather
20 the dispersing agents are provided in an amount suitable for providing meta-stable peracid compositions generated from the premix after acidification, before further dilution for application. The most efficient dispersing agents were found to be anionic surfactants, and this type of surfactant is known to have high foaming profile. For applications which involves mechanical actions (e.g. CIP sanitizing),
25 the high foam property of the composition is undesirable. Thus, in addition to economic reason, it is preferred to use a minimum amount of the dispersing agent to achieve a meta-stable peracid composition to meet the application of use requirements.

According to an embodiment of the invention less than about 10 ppm,
30 preferably less than about 9 ppm, less than about 8 ppm, less than about 7 ppm, less than about 6 ppm, less than about 5 ppm, less than about 4 ppm, less than about 3 ppm, less than about 2 ppm, or less than about 1 ppm of a dispersing agent is

included in the generated peracid chemistry as a result of the use of a surfactant dispersing agent in a concentrated premix formulation according to the invention. This is distinct from the level of surfactants in use solutions of a traditional peracid chemistry, where the amounts of surfactants are normally in excess of about 50 ppm, in excess of about 60 ppm, in excess of about 70 ppm, in excess of about 80 ppm, in excess of about 90 ppm, or in excess of about 100 ppm.

According to a further embodiment of the invention less than about 2% dispersing agent is present in the premix composition, wherein at least about 5%, about 6%, about 7%, about 8% or about 9% are required to provide the stable, clear solution of a generated peracid chemistry when acidified. This is distinct from the generated peracid chemistry according to the invention wherein a meta stable chemistry is generated. Although not wishing to be limited to a particular theory of mechanism of action of the invention, the generated meta-stable composition is a milky colored composition having stability for at least a few hours.

According to an embodiment of the invention, the use of a solvent (e.g. ethanol) is an efficient way to make a stable premix composition. Solvents suitable for the concentrated premix formulations according to the invention include, for example, organic solvents such as alcohol, ether or ketone. Preferably, the solvent is a water soluble alcohol, such as ethanol, methanol, propanol, isopropanol and/or butanol. As one skilled in the art will ascertain the various isomers of the solvents, including alcohols, are further included within the scope of the solvents suitable for use with the concentrated premix formulations of the invention.

Beneficially, the use of concentrated premix formulation still does not require the use of any chelators and/or stabilizers. As a result, regardless of whether individual reagents or concentrated premix formulations are utilized according to the invention, both the reagents and the peracid compositions generated according to the invention provide sustainable chemistries as a result of the elimination of the use of various stabilizers and/or additional amounts of chemistry required to drive the formation of traditional peracid chemistry. As a result of reduced input of reagents for the compositions according to the invention (e.g. resulting from the use of a non-equilibrium reaction) there is a significantly reduced waste stream (e.g. any reagents and/or percentage of composition not impacting the micro-efficacy of the

compositions). Instead the present invention provides increased amounts of post-reaction products (e.g. peracids) with decreased amounts of unreacted reagents.

In an aspect of the invention, a premix formulation may deliver the ester of a polyhydric alcohol and a carboxylic acid and the oxidizing agent. In one aspect a
5 premix formulation includes an ester of a polyhydric alcohol and a carboxylic acid, an oxidizing agent and a dispersing agent. In another aspect a premix formulation includes an ester of a polyhydric alcohol and a carboxylic acid, an oxidizing agent, a dispersing agent and water.

Suitable dispersing agents for use according to the concentrated premix
10 formulations of the invention include polymers, surface active agents or any compounds which will help to achieve a meta-stable solution after the ester perhydrolysis through the interaction with the peroxy fatty acids generated through perhydrolysis. These may include, for example, sulfonated oleic acids (SOA), 1-octanesulfonic acid (NAS), sodium lauryl sulfonates (SLS) and the like. In another
15 aspect a premix formulation includes an ester of a polyhydric alcohol and a carboxylic acid, an oxidizing agent and a solvent. Ethanol and methanol are examples of suitable solvents for use in stabilizing the concentrated premix formulation according to the invention. The use of the solvent in certain
embodiments obviates the use of a dispersing agent for premix stability. However, in
20 alternative embodiments a premix formulation may include an ester of a polyhydric alcohol and a carboxylic acid, an oxidizing agent, a dispersing agent and a solvent. Without wishing to be limited to a particular theory or mechanism of action of the invention, the combined use of a dispersing agent and a solvent within a
concentrated premix formulation reduces the overall need for a surfactant dispersing
25 agent in the premix composition.

In still another aspect a concentrated premix formulation includes an oxidizing agent and a dispersing agent.

In certain embodiments, the concentrated premix composition includes about 0.001 to about 90 wt-% ester of the polyhydric alcohol and a carboxylic acid, about
30 0.1 to about 90 wt-% ester, about 1 to about 75 wt-% ester, about 10 to about 75 wt-% ester, about 25 to about 75 wt-% ester, about 30 to about 70 wt-% ester, or about 30 to about 65 wt-% ester.

In certain embodiments, the concentrated premix composition further includes about 0.001 to about 99 wt-% oxidizing agent, about 0.1 to about 95 wt-% oxidizing agent, about 1 to about 90 wt-% oxidizing agent, about 2.5 to about 60 wt-% oxidizing agent, about 5 to about 50 wt-% oxidizing agent, or about 10 to about 40 wt-% oxidizing agent.

In certain embodiments, the concentrated premix composition further includes about 0.001 to about 50 wt-% dispersing agent, about 0.1 to about 40 wt-% dispersing agent, about 1 to about 30 wt-% dispersing agent, about 5 to about 30 wt-% dispersing agent, about 5 to about 20 wt-% dispersing agent, or about 5 to about 15 wt-% dispersing agent. The amount of dispersing agent is selected to ensure that only enough dispersing agent to obtain a meta-stable solution after perhydrolysis and acidification. Beneficially according to the invention, the premix formulations do not contain sufficient dispersing agent to obtain a one phase premix solution.

In certain embodiments, the concentrated premix composition further includes about 0.001 to about 80 wt-% solvent, about 0.1 to about 40 wt-% solvent, about 1 to about 30 wt-% solvent, about 5 to about 30 wt-% solvent, about 5 to about 20 wt-% solvent, or about 5 to about 15 wt-% solvent. 3 The level of solvent is selected to ensure the sufficient amount to solubilize the ester(s) of polyhydric alcohol in the concentrated premix formulation. As one skilled in the art will ascertain the amount of solvent required for such solubilization will vary depending upon the type and level of ester(s) in the premix composition.

In certain embodiments, the concentrated premix composition further includes about 0.001 to about 90 wt-% water, about 0.1 to about 80 wt-% water, about 1 to about 75 wt-% water, about 5 to about 60 wt-% water, about 10 to about 50 wt-% water, or about 20 to about 40 wt-% water. The premix compositions can include any of these ranges or amounts, including those not modified by about.

The pH of the concentrated premix formulation according to the invention is preferably between 2 and about 10, preferably between about 3 and about 9, and more preferably between about 5 and about 7. Thereafter the pH of the premix formulation is combined with an a source of alkalinity to increase the pH to a pH greater than about 12, greater than about 12.5, or greater than about 13 according to the invention.

Methods of Making Peracid Compositions

In some aspects, the present disclosure provides methods for on-site generation of the peroxycarboxylic acid forming compositions and peroxycarboxylic acid disclosed herein. According to an embodiment of the invention, the methods of on-site generation are particularly suitable for batch preparation (*i.e.* batch mode) of peroxycarboxylic acid forming compositions and peroxycarboxylic acids. Batch preparations are most desirable for on-site production having intermittent needs for the peroxycarboxylic acid forming compositions and peroxycarboxylic acids. However, as one skilled in the art will ascertain, the methods of on-site generation may be modified to provide continuous production of the peroxycarboxylic acid forming compositions and peroxycarboxylic acids.

The method includes combining at least one ester of a polyhydric alcohol and a C1 to C18 carboxylic acid, a source of alkalinity and an oxidizing agent in a reaction vessel. The method may include inputting a user- or system-controlled peroxycarboxylic acid forming composition or peroxycarboxylic acid formulation that is desired for a particular use. The user- or system-controlled input may be put into a control software for an adjustable biocide formulator or generator system, wherein said input formulation selects an individual or mixed peroxycarboxylic acid forming composition or peroxycarboxylic acid and the corresponding volume or mass of the chemistry for onsite generation.

In some embodiments a user controls the input for the on-site chemistry generation. In further embodiments, a system-controlled input may include, for example, a CIP process, bottle washer, aseptic filler, vegetable wash or rinse sink, 3rd sink sanitizing sink, textile bleaching process and combinations thereof.

In some embodiments, the user- or system-input selects either a single or multiple reaction vessel mode for the peroxycarboxylic acid and/or mixed peroxycarboxylic acid or peroxycarboxylic acid forming composition generation. As a result of the reaction vessel mode selected by the input, the addition of the reaction reagents, including at least the esters, source of alkalinity and oxidizing agent, may be added in parallel or sequentially. The reagents can be combined in any suitable manner according to the invention and mixed for an amount of time

effective to form the desired percarboxylic acid forming composition or percarboxylic acid concentration.

According to the invention, reagents may be added substantially simultaneously to a single reaction vessel, and mixed for an amount of time effective
5 to form the desired concentration. Alternatively, reagents may be added sequentially to a single reaction vessel or separate reaction vessels. Still further, reagents may be combined from separate reaction vessels into an additional reaction vessel or a reservoir (e.g. dilution tank).

In some embodiments, the pH of the reaction mixture is greater than about
10 12. In other embodiments, the reaction mixture is greater than about 12.5, or greater than about 13.

According to an embodiment of the invention, the reagents are mixed in one or more reaction vessels for a period of time sufficient for the perhydrolysis reaction to occur. In some embodiments, the reagents are mixed for about 5 to about 30
15 minutes. In other embodiments, the reagents are mixed for about 10, about 15, about 20, or about 25 minutes. The mixing may take place using a variety of mixing mechanisms, including for example, an impeller or a mechanical blade mixer, such as a mixer having a variable speed control motor to achieve homogeneous blending of reagents.

20 In additional preferred embodiments the mix order of reagents are controlled to produce a consistent output of peracid chemistry without any fouling (e.g. precipitation) of the reagents. In one aspect of the invention, the source of alkalinity (e.g. sodium hydroxide or caustic soda) is combined with water (e.g. diluted) prior to the addition of the ester source. As disclosed herein the ester source can further
25 be provided in an ester premix (e.g. ester/peroxide premix).

The concentration of reagents, in addition to mixing order, can further be used to control the production of the percarboxylic acid composition. In a preferred embodiment, the concentration of the source of alkalinity is diluted to produce a consistent output of chemistry without any fouling (e.g. precipitation) of the
30 reagents. In one aspect the concentrated alkaline solution (e.g. NaOH) is diluted with a water source before the ester component is combined with the reagents. Although not intending to be limited according to any theory of the invention and/or

mechanism of action, the invention demonstrates superior chemistry generation when a system delivers a source of alkalinity (e.g. NaOH solution) that is no more than about 50%, preferably no more than about 40% on an actives basis before combining with the ester reagent to initiate the peracid production reaction.

5 According to preferred methods of making the peracid chemistry, an ex-situ ABF generator system using a injection manifold to combine an alkaline source, an ester precursor, a peroxygen source and optionally water for production of a peroxy acid is used. Preferably the alkaline source is caustic soda, wherein the caustic stream feeding the manifold is diluted. In an aspect the caustic can be diluted within
10 the manifold to the target concentration of less than about 50%, preferably less than about 40% by weight. In an additional embodiment, the ester is added to the system downstream (e.g. after the addition of the diluted NaOH solution).

 In an embodiment, the extent of the ester perhydrolysis reaction is measured using one or more measurement devices. Suitable measurement devices measures
15 one or more reaction kinetics or system operations, including for example fluorescence, weight, flow, capacitive level, pH, oxidation reduction potential, pressure, temperature and combinations thereof, as disclosed herein. According to an embodiment, the measurement devices may be used to determine the need and/or timing to add an acid or aqueous acidic solution to dilute the peroxycarboxylic acid
20 forming composition to form the peroxycarboxylic acid composition. In some embodiments the addition of an acid or aqueous acidic solution decreases the pH of the reaction mixture from greater than about 12 to a neutralized pH of about 1.0 to about 8.0.

 In an embodiment of the invention, the peroxycarboxylic acid forming
25 composition is dispensed for use in a cleaning process. According to an embodiment, the peroxycarboxylic acid forming composition may be generated in batches approximately at least about every 15 minutes, preferably about every 10 minutes, and more preferably about every 5 minutes. An acid or aqueous acidic solution may be added to the peroxycarboxylic acid forming composition outside of
30 the system according to the invention.

 Preferably, the ABF system, including the reaction vessels, are cleaned between batches of peroxycarboxylic acid forming compositions. Rinsing of the

ABF system is expected to have an impact on yield of the peroxycarboxylic acid forming compositions. According to an embodiment of the invention, the system is rinsed (*e.g.* feed pump lines flushed) with warm/hot water between batches, and/or at regularly scheduled intervals to comply with regulatory requirements (*e.g.*

5 sanitizing regulations), as one skilled in the art shall ascertain.

A particularly suitable embodiment of the invention forms a mixed percarboxylic acid composition by using more than one ester of a polyhydric alcohol and a C1 to C18 carboxylic acid as starting reagents. For example, in some embodiments, a mixed percarboxylic acid composition including peracetic acid and

10 peroctanoic acid is formed. To form this composition, an ester of a polyhydric alcohol and a C1 carboxylic acid is combined with an ester of a polyhydric alcohol and a C8 carboxylic acid, a source of alkalinity, and an oxidizing agent. When forming a mixed peracid composition, the order of addition can be varied depending on the reaction conditions. For example, in some embodiments, all of the reagents

15 can be combined and mixed in one step. Alternatively, in some embodiments, one of the esters can be added to a reaction vessel, with an oxidizing agent, and a source of alkalinity added sequentially. This mixture can be allowed to react for an effective amount of time, prior to the second ester being added to the reaction mixture. Preparing the mixed percarboxylic acid system in a stepwise manner also

20 allows for control of the reaction temperature. For example, by splitting the perhydrolysis reactions into two steps, the overall temperature of the reaction mixture is lower.

In some aspects of the invention, the order of addition and time for reaction can be varied according to the desired percarboxylic acid composition. That is, the

25 reaction can be controlled so as to favor the reaction conditions for formation of each of the percarboxylic acids individually. For example, if it is known that one of the esters has a kinetically slower perhydrolysis reaction rate, that ester can be added to the reaction vessel first. After an amount of time sufficient to maximize the percarboxylic acid formation of the first ester, the second ester with a kinetically

30 faster perhydrolysis reaction rate can be added to the reaction vessel.

According to additional aspects of the invention, the selected batch size of a desired percarboxylic acid forming composition or percarboxylic acid impacts the

reaction kinetics. According to the invention, a user- or system-inputted batch size (*i.e.* volume) to the ABF system impacts the reaction kinetics. Although not intending to be limited to a particular theory, when generating various batch sizes with the ABF system according to the invention, not all reactions are linearly time-scaled, such that a larger batch size (*i.e.* hundreds of gallons) may require a different timing sequence than a smaller batch size (*i.e.* tens of gallons) depending on the reaction kinetics and various mixing parameters. The present invention accommodates the changes in user- or system-inputted batch sizes, such that for different volumes of peracid compositions the time constants for its formulation will vary.

In some aspects, the present disclosure provides methods for forming an antimicrobial and/or disinfecting composition. The methods include providing a mixed peroxycarboxylic acid forming composition. The mixed peroxycarboxylic acid forming composition includes: a first ester of a polyhydric alcohol and a C1 to C18 carboxylic acid, for example a C1 to C4 carboxylic acid; a second ester of a polyhydric alcohol and a C1 to C18 carboxylic acid, for example a C8 to C11 carboxylic acid; a source of alkalinity; and an oxidizing agent. After allowing the reaction mixture to react for a sufficient amount of time, a mixed percarboxylic acid composition is formed. The mixed peroxycarboxylic acid composition is diluted with an acidic aqueous solution. In some embodiments, the mixed peroxycarboxylic acid composition is diluted with an amount of an acidic aqueous solution effective to provide the diluted composition with a pH of about 1.0 to about 8.0.

In other aspects, the present disclosure provides methods for forming an antimicrobial and/or disinfecting composition including a single percarboxylic acid. The methods include providing a peroxycarboxylic acid forming composition. The composition includes: an ester of a polyhydric alcohol and a C1 to C18 carboxylic acid; a source of alkalinity; and an oxidizing agent, wherein said composition has a pH greater than 12. The peroxycarboxylic acid forming composition is then diluted with an acidic aqueous solution. In some embodiments, the diluted acidic peroxycarboxylic acid composition has a pH of about 1.0 to about 8.0.

Any acidic solution can be used to dilute the peroxycarboxylic acid compositions. In an embodiment, the acidulant includes an inorganic acid. Suitable

inorganic acids include, but are not limited to, sulfuric acid, sodium bisulfate, phosphoric acid, nitric acid, hydrochloric acid. In some embodiments, the acidulant includes an organic acid. Suitable organic acids include, but are not limited to, methane sulfonic acid, ethane sulfonic acid, propane sulfonic acid, butane sulfonic acid, xylene sulfonic acid, benzene sulfonic acid, formic acid, acetic acid, mono, di, or tri-halocarboxylic acids, picolinic acid, dipicolinic acid, and mixtures thereof. In some embodiments, the compositions of the present invention are free or substantially free of a phosphorous based acid.

Methods Employing Peracid Compositions

In some aspects, the present disclosure includes methods of using the peroxycarboxylic acid forming compositions disclosed herein. In some aspects, the methods of using the compositions employ a chemistry having a pH of from about 0 to about 5 for various antimicrobial and/or bleaching applications. In other aspects, the methods of using the compositions employ a chemistry having a pH of from about 5 to about 9 for various antimicrobial and/or bleaching applications. In still further aspects, the methods of using the compositions employ a chemistry having a pH of from about 5 to about 14 for various bleaching applications.

In some aspects, the present disclosure includes methods of using the peroxycarboxylic acid forming compositions and/or peroxycarboxylic acids disclosed herein. Peracid compositions generated according to the embodiments of the invention may be used for a variety of user-identified biocidal and/or antimicrobial purposes. In some aspects, the on-site generated peracid compositions may be employed for antimicrobial and/or bleaching methods of use. In further aspects, the on-site generated peracid compositions may be employed for any sanitizing methods of use. For example, the invention includes a method for reducing a microbial population, a method for reducing the population of a microorganism on skin, a method for treating a disease of skin, a method for reducing an odor, or a method for bleaching. These methods can operate on an object, surface, in a body or stream of water or a gas, or the like, by contacting the object, surface, body, or stream with a peracid composition of the invention. Contacting can include any of numerous methods for applying a composition, such as spraying the composition, immersing the object in the composition, foam or gel

treating the object with the composition, wiping the composition or a combination thereof

In some aspects, a composition obtained according to the methods and apparatus of the present invention includes an amount of a peracid composition of the present invention effective for killing one or more of the food-borne pathogenic bacteria associated with a food product, including, but not limited to, *Salmonella typhimurium*, *Salmonellajaviana*, *Campylobacterjejuni*, *Listeria monocytogenes*, and *Escherichia coli* O157:H7, yeast, and mold. In some embodiments, the compositions obtained according to the methods and apparatus of the present invention include an amount of a peracid composition effective for killing one or more of the pathogenic bacteria associated with a health care surfaces and environments including, but not limited to, *Salmonella typhimurium*, *Staphylococcus aureus*, *Salmonella choleraesurus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *mycobacteria*, yeast, and mold. The compositions obtained according to the methods and apparatus of the present invention have activity against a wide variety of microorganisms such as Gram positive (for example, *Listeria monocytogenes* or *Staphylococcus aureus*) and Gram negative (for example, *Escherichia coli* or *Pseudomonas aeruginosa*) bacteria, yeast, molds, bacterial spores, viruses, etc. The compositions obtained according to the methods and apparatus of the present invention, as described above, have activity against a wide variety of human pathogens. The present compositions obtained according to the methods and apparatus of the present invention can kill a wide variety of microorganisms on a food processing surface, on the surface of a food product, in water used for washing or processing of food product, on a health care surface, in a health care environment or the like.

The compositions obtained according to the methods and apparatus of the invention can be used for a variety of domestic or industrial applications, *e.g.*, to reduce microbial or viral populations on a surface or object or in a body or stream of water. The compositions can be applied in a variety of areas including kitchens, bathrooms, factories, hospitals, dental offices, restaurants, clean in place applications, laundry or textile applications and food plants, and can be applied to a variety of hard or soft surfaces having smooth, irregular or porous topography.

Suitable hard surfaces include, for example, architectural surfaces (*e.g.*, floors, walls, windows, sinks, tables, counters and signs); eating utensils; hard-surface medical or surgical instruments and devices; and hard-surface packaging. Such hard surfaces can be made from a variety of materials including, for example, ceramic,
5 metal, glass, wood or hard plastic.

Suitable soft surfaces include, for example, paper; filter media, hospital and surgical linens and garments; soft-surface medical or surgical instruments and devices; and soft-surface packaging. Such soft surfaces can be made from a variety of materials including, for example, paper, fiber, woven or nonwoven fabric, soft
10 plastics and elastomers. The compositions obtained according to the methods and apparatus of the invention can also be applied to soft surfaces such as food and skin (*e.g.*, a hand). The present compositions can be employed as a foaming or nonfoaming environmental sanitizer or disinfectant.

The peracid compositions obtained according to the methods and system of
15 the present invention can be included in products such as sterilants, sanitizers, disinfectants, preservatives, deodorizers, antiseptics, fungicides, germicides, sporicides, virucides, detergents, bleaches, hard surface cleaners, hand soaps, waterless hand sanitizers, and pre- or post-surgical scrubs.

The compositions can also be used in veterinary products such as
20 mammalian skin treatments or in products for sanitizing or disinfecting animal enclosures, pens, watering stations, and veterinary treatment areas such as inspection tables and operation rooms. The present compositions can be employed in an antimicrobial foot bath for livestock or people. The compositions can also be employed as an antimicrobial teat dip.

25 In some aspects, the compositions obtained according to the methods and apparatus of the present invention can be employed for reducing the population of pathogenic microorganisms, such as pathogens of humans, animals, and the like. As one skilled in the art will ascertain, the reducing of pathogenic microorganism populations is particularly suitable for healthcare and institutional applications of
30 use. The compositions exhibit activity against pathogens including fungi, molds, bacteria, spores, and viruses, for example, *S. aureus*, *E. coli*, *Streptococci*, *Legionella*, *Pseudomonas aeruginosa*, *mycobacteria*, *tuberculosis*, phages, or the

like. Such pathogens can cause a variety of diseases and disorders, including mastitis or other mammalian milking diseases, tuberculosis, and the like. The compositions of the present invention can reduce the population of microorganisms on skin or other external or mucosal surfaces of an animal. In addition, the present
5 compositions can kill pathogenic microorganisms that spread through transfer by water, air, or a surface substrate. The composition need only be applied to the skin, other external or mucosal surfaces of an animal water, air, or surface.

The peracid compositions obtained according to the methods and apparatus of the present invention can also be used on foods and plant species to reduce
10 surface microbial populations; used at manufacturing or processing sites handling such foods and plant species; or used to treat process waters around such sites. For example, the compositions can be used on food transport lines (*e.g.*, as belt sprays); boot and hand-wash dip-pans; food storage facilities; anti-spoilage air circulation systems; refrigeration and cooler equipment; beverage chillers and warmers,
15 blanchers, cutting boards, third sink areas, and meat chillers or scalding devices. The compositions of the invention can be used to treat produce transport waters such as those found in flumes, pipe transports, cutters, slicers, blanchers, retort systems, washers, and the like. Particular foodstuffs that can be treated with compositions of the invention include, but are not limited to, eggs, meats, seeds, leaves, fruits and
20 vegetables. Particular plant surfaces include both harvested and growing leaves, roots, seeds, skins or shells, stems, stalks, tubers, corms, fruit, and the like. The compositions may also be used to treat animal carcasses to reduce both pathogenic and non-pathogenic microbial levels.

The compositions can also be used to treat waste water where both its
25 antimicrobial function and its oxidant properties can be utilized. Aside from the microbial issues surrounding waste water, it is often rich in malodorous compounds of reduced sulfur, nitrogen or phosphorous. A strong oxidant such as the present invention converts these compounds efficiently to their odor free derivatives *e.g.* the sulfates, phosphates and amine oxides. These same properties are very useful in the
30 pulp and paper industry where the property of bleaching is also of great utility.

In some aspects, the compositions obtained according to the methods and apparatus of the present invention are useful in the cleaning or sanitizing of

containers, processing facilities, or equipment in the food service or food processing industries. The compositions have particular value for use on food packaging materials and equipment, and especially for cold or hot aseptic packaging.

Examples of process facilities in which the composition of the invention can be

5 employed include a milk line dairy, a continuous brewing system, food processing lines such as pumpable food systems and beverage lines, etc. Food service wares can be treated with an antimicrobial and/or disinfected with the composition of the invention. For example, the compositions can also be used on or in ware wash machines, dishware, bottle washers, bottle chillers, warmers, third sink washers,
10 cutting areas (*e.g.*, water knives, slicers, cutters and saws), egg washers or the like. Particular treatable surfaces include, but are not limited to, packaging such as cartons, bottles, films and resins; dish ware such as glasses, plates, utensils, pots and pans; ware wash machines; exposed food preparation area surfaces such as sinks, counters, tables, floors and walls; processing equipment such as tanks, vats, lines,
15 pumps and hoses (*e.g.*, dairy processing equipment for processing milk, cheese, ice cream and other dairy products); and transportation vehicles. Containers include glass bottles, PVC or polyolefin film sacks, cans, polyester, PEN or PET bottles of various volumes (100 ml to 2 liter, etc.), one gallon milk containers, paper board juice or milk containers, etc.

20 The compositions can also be used on or in other industrial equipment and in other industrial process streams such as heaters, cooling towers, boilers, retort waters, rinse waters, aseptic packaging wash waters, and the like. The compositions can be used to treat microbes and odors in recreational waters such as in pools, spas, recreational flumes and water slides, fountains, and the like. The composition can
25 also be used in treating microbes found in aqueous systems associated with petroleum or LP gas recovery or fermentation processes and pulp and paper processes and the like.

A filter containing peracid compositions of the present invention can reduce the population of microorganisms in air and liquids. Such a filter can remove water
30 and air-born pathogens such as *Legionella*.

The compositions obtained according to the methods and apparatus of the present invention can be employed for reducing the population of microbes, fruit flies, or other insect larva on a drain or other surface.

The compositions of the present invention can also be employed by dipping
5 food processing equipment into the use solution, soaking the equipment for a time sufficient to sanitize or destain the equipment, and wiping or draining excess solution off the equipment. The compositions of the present invention may be further employed by spraying or wiping food processing surfaces with the use solution, keeping the surfaces wet for a time sufficient to sanitize the surfaces, and
10 removing excess solution by wiping, draining vertically, vacuuming, etc.

The compositions obtained according to the methods and system of the present invention may also be used in a method of sanitizing hard surfaces such as institutional type equipment, utensils, dishes, health care equipment or tools, and other hard surfaces.

15 The compositions of the present invention can also be used for laundry or textile applications. The compositions can be employed by rinsing laundry or textile surfaces with the use solution, keeping the surfaces wet for a sufficient time to wash, destain, sanitize, bleach and/or rinse the surface.

The peracid compositions can be applied to microbes or to soiled or cleaned
20 surfaces using a variety of methods. These methods can operate on an object, surface, in a body or stream of water or a gas, or the like, by contacting the object, surface, body, or stream with a composition of the invention. Contacting can include any of numerous methods for applying a composition, such as spraying the composition, immersing the object in the composition, rinsing the composition,
25 foam or gel treating the object with the composition, applying with a wipe system or a combination thereof.

A concentrate or use concentration of a peracid composition obtained according to the methods and apparatus of the present invention can be applied to or brought into contact with an object by any conventional method or apparatus for
30 applying an antimicrobial or cleaning composition to an object. For example, the object can be wiped with, sprayed with, foamed on, and/or immersed in the composition, or a use solution made from the composition. The compositions can

be sprayed, foamed, or wiped onto a surface; the composition can be caused to flow over the surface, or the surface can be dipped into the composition. Contacting can be manual or by machine. Food processing surfaces, food products, food processing or transport waters, and the like can be treated with liquid, foam, gel, aerosol, gas, wax, solid, or powdered peracid compositions according to the invention, or solutions containing these compositions.

Other hard surface cleaning applications for the compositions include clean-in-place systems (CIP), clean-out-of-place systems (COP), washer-decontaminators, sterilizers, textile laundry machines, ultra and nano-filtration systems and indoor air filters. COP systems can include readily accessible systems including wash tanks, soaking vessels, mop buckets, holding tanks, scrub sinks, vehicle parts washers, non-continuous batch washers and systems, and the like. CIP systems include the internal components of tanks, lines, pumps and other process equipment used for processing typically liquid product streams such as beverages, milk, juices.

A method of sanitizing substantially fixed in-place process facilities includes the following steps. A composition in accordance with various embodiments of the invention is introduced into the process facilities at a temperature in the range of about 4 °C to 60 °C. After introduction of the composition, the solution is held in a container or circulated throughout the system for a time sufficient to sanitize the process facilities (*e.g.*, to kill undesirable microorganisms). After the surfaces have been sanitized by means of the present compositions, the solution is drained. Upon completion of the sanitizing step, the system optionally may be rinsed with other materials such as potable water. The compositions can be circulated through the process facilities for 10 minutes or less.

The present methods can include delivering the present composition via air delivery to the clean-in-place or other surfaces such as those inside pipes and tanks. This method of air delivery can reduce the volume of solution required.

Methods for Contacting a Food Product

In some aspects, the present invention provides methods for contacting a food product with compositions according to the invention employing any method or apparatus suitable for applying such compositions. For example, in some embodiments, the food product is contacted by the compositions with a spray of the

compositions, by immersion in the compositions, by foam or gel treating with the compositions. Contact with a spray, a foam, a gel, or by immersion can be accomplished by a variety of methods known to those of skill in the art for applying antimicrobial agents to food. Contacting the food product can occur in any location
5 in which the food product might be found, such as field, processing site or plant, vehicle, warehouse, store, restaurant, or home. These same methods can also be adapted to apply the compositions of the present invention to other objects.

The present methods require a certain minimal contact time of the compositions with food product for occurrence of significant antimicrobial effect.
10 The contact time can vary with concentration of the use compositions, method of applying the use compositions, temperature of the use compositions, amount of soil on the food product, number of microorganisms on the food product, type of antimicrobial agent, or the like. The exposure time can be at least about 5 to about 15 seconds. In some embodiments, the exposure time is about 15 to about 30
15 seconds. In other embodiments, the exposure time is at least about 30 seconds.

In some embodiments, the method for washing a food product employs a pressure spray including compositions of the present invention. During application of the spray solution on the food product, the surface of the food product can be moved with mechanical action, *e.g.*, agitated, rubbed, brushed, etc. Agitation can be
20 by physical scrubbing of the food product, through the action of the spray solution under pressure, through sonication, or by other methods. Agitation increases the efficacy of the spray solution in killing micro-organisms, perhaps due to better exposure of the solution into the crevasses or small colonies containing the micro-organisms. The spray solution, before application, can also be heated to a
25 temperature of about 15 to 20 °C, for example, about 20 to 60 °C to increase efficacy. The spray stabilized compositions can be left on the food product for a sufficient amount of time to suitably reduce the population of microorganisms, and then rinsed, drained, or evaporated off the food product. Application of the material by spray can be accomplished using a manual spray wand application, an
30 automatic spray of food product moving along a production line using multiple spray heads to ensure complete contact, or other spray apparatus. One automatic spray application involves the use of a spray booth. The spray booth substantially

confines the sprayed compositions to within the booth. The production line moves the food product through the entryway into the spray booth in which the food product is sprayed on all its exterior surfaces with sprays within the booth. After a complete coverage of the material and drainage of the material from the food product within the booth, the food product can then exit the booth. The spray booth can include steam jets that can be used to apply the stabilized compounds of the invention. These steam jets can be used in combination with cooling water to ensure that the treatment reaching the food product surface is less than 65°C, *e.g.*, less than 60°C. The temperature of the spray on the food product is important to ensure that the food product is not substantially altered (cooked) by the temperature of the spray. The spray pattern can be virtually any useful spray pattern.

Immersing a food product in the liquid compositions of the present invention can be accomplished by any of a variety of methods known to those of skill in the art. For example, the food product can be placed into a tank or bath containing the compositions. Alternatively, the food product can be transported or processed in a flume of the compositions. The washing solution can be agitated to increase the efficacy of the solution and the speed at which the solution reduces micro-organisms accompanying the food product. Agitation can be obtained by conventional methods, including ultrasonics, aeration by bubbling air through the solution, by mechanical methods, such as strainers, paddles, brushes, pump driven liquid jets, or by combinations of these methods. The washing solution can be heated to increase the efficacy of the solution in killing micro-organisms. After the food product has been immersed for a time sufficient for the desired antimicrobial effect, the food product can be removed from the bath or flume and the compositions can be rinsed, drained, or evaporated off the food product.

In other embodiments, a food product can be treated with a foaming version of the compositions of the present invention. The foam can be prepared by mixing foaming surfactants with the washing solution at time of use. The foaming surfactants can be nonionic, anionic or cationic in nature. Examples of useful surfactant types include, but are not limited to the following: alcohol ethoxylates, alcohol ethoxylate carboxylate, amine oxides, alkyl sulfates, alkyl ether sulfate, sulfonates, including, for example, alkyl aryl sulfonates, quaternary ammonium

compounds, alkyl sarcosines, betaines and alkyl amides. The foaming surfactant is typically mixed at time of use with the washing solution. Use solution levels of the foaming agents is from about 50 ppm to about 2.0 wt-%. At time of use, compressed air can be injected into the mixture, then applied to the food product surface through a foam application device such as a tank foamer or an aspirated wall mounted foamer.

In some embodiments, a food product can be treated with a thickened or gelled version of the compositions of the present invention. In the thickened or gelled state the washing solution remains in contact with the food product surface for longer periods of time, thus increasing the antimicrobial efficacy. The thickened or gelled solution will also adhere to vertical surfaces. The compositions can be thickened or gelled using existing technologies such as: xanthan gum, polymeric thickeners, cellulose thickeners, or the like. Rod micelle forming systems such as amine oxides and anionic counter ions could also be used. The thickeners or gel forming agents can be used either in the concentrated product or mixing with the washing solution, at time of use. Typical use levels of thickeners or gel agents range from about 100 ppm to about 10 wt-%.

Methods for Beverage, Food, and Pharmaceutical Processing

The compositions of the present invention can be used in the manufacture of beverage, food, and pharmaceutical materials including fruit juice, dairy products, malt beverages, soybean-based products, yogurts, baby foods, bottled water products, teas, cough medicines, drugs, and soft drinks. The compositions of the present invention can be used to sanitize, disinfect, act as a sporicide for, or sterilize bottles, pumps, lines, tanks and mixing equipment used in the manufacture of such beverages. Further, the compositions of the present invention can be used in aseptic, cold filling operations in which the interior of the food, beverage, or pharmaceutical container is sanitized or sterilized prior to filling. In such operations, a container can be contacted with the compositions, typically using a spray, dipping, or filling device to intimately contact the inside of the container with the compositions, for a sufficient period of time to reduce microorganism populations within the container. The container can then be emptied of the amount of sanitizer or sterilant used. After emptying, the container can be rinsed with potable water or sterilized water and

again emptied. After rinsing, the container can be filled with the beverage, food, or pharmaceutical. The container can then be sealed, capped or closed and then packed for shipment for ultimate sale. The sealed container can be autoclaved or retorted for added microorganism kill.

5 In food, beverage, or pharmaceutical manufacturing, fungal microorganisms of the genus *Chaetomium* or *Arthrinium*, and spores or bacteria of the genus *Bacillus spp.* can be a significant problem in bottling processes, particularly in cold aseptic bottling processes. The compositions of the present invention can be used for the purpose of controlling or substantially reducing (by more than a 5 log₁₀ reduction)
10 the number of *Chaetomium* or *Arthrinium* or *Bacillus* microorganisms in beverage or food or pharmaceutical bottling lines using cold aseptic bottling techniques.

 In such techniques, metallic, aluminum or steel cans can be filled, glass bottles or containers can be filled, or plastic (PET or PBT or PEN) bottles, and the like can be filled using cold aseptic filling techniques. In such processes, the
15 compositions of the invention can be used to sanitize the interior of beverage containers prior to filling with the carbonated (or noncarbonated) beverage. Typical carbonated beverages in this application include, but are not limited to, cola beverages, fruit beverages, ginger ale beverages, root beer beverages, iced tea beverages which may be non-carbonated, and other common beverages considered
20 soft drinks. The compositions of the invention can be used to sanitize both the tanks, lines, pumps, and other equipment used for the manufacture and storage of the soft drink material and also used in the bottling or containers for the beverages. In an embodiment, the compositions are useful for killing both bacterial and fungal microorganisms that can be present on the surfaces of the production equipment and
25 beverage containers.

Methods for Industrial Processing

 In some aspects, the invention includes methods of using the peroxy-carboxylic acid forming compositions and/or peroxy-carboxylic acids to prevent biological fouling in various industrial processes and industries, including
30 oil and gas operations, to control microorganism growth, eliminate microbial contamination, limit or prevent biological fouling in liquid systems, process waters or on the surfaces of equipment that come in contact with such liquid systems. As

referred to herein, microbial contamination can occur in various industrial liquid systems including, but not limited to, air-borne contamination, water make-up, process leaks and improperly cleaned equipment. In another aspect, the peroxydicarboxylic acid forming compositions and/or peroxydicarboxylic acids are used to control the growth of microorganisms in water used in various oil and gas operations. In a further aspect, the compositions are suitable for incorporating into fracturing fluids to control or eliminate microorganisms.

For the various industrial processes disclosed herein, "liquid system" refers to flood waters or an environment within at least one artificial artifact, containing a substantial amount of liquid that is capable of undergoing biological fouling, it includes but is not limited to industrial liquid systems, industrial water systems, liquid process streams, industrial liquid process streams, industrial process water systems, process water applications, process waters, utility waters, water used in manufacturing, water used in industrial services, aqueous liquid streams, liquid streams containing two or more liquid phases, and any combination thereof.

In at least one embodiment this technology would be applicable to any process or utility liquid system where microorganisms are known to grow and are an issue, and biocides are added. Examples of some industrial process water systems where the method of this invention could be applied are in process water applications (flume water, shower water, washers, thermal processing waters, brewing, fermentation, CIP (clean in place), hard surface sanitization, etc.), Ethanol/Bio-fuels process waters, pretreatment and utility waters (membrane systems, ion-exchange beds), water used in the process/manufacture of paper, ceiling tiles, fiber board, microelectronics, E-coat or electro deposition applications, process cleaning, oil exploration and energy services (completion and work over fluids, drilling additive fluids, fracturing fluids, flood waters, etc.; oil fields - oil and gas wells/flow line, water systems, gas systems, etc.), and in particular water systems where the installed process equipment exhibits lowered compatibility to halogenated biocides.

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, numerous equivalents to the specific procedures,

embodiments, claims, and examples described herein. Such equivalents are considered to be within the scope of this invention and covered by the claims appended hereto. The contents of all references, patents, and patent applications cited throughout this application are hereby incorporated by reference. The
5 invention is further illustrated by the following examples, which should not be construed as further limiting.

All publications and patent applications in this specification are indicative of the level of ordinary skill in the art to which this invention pertains. All publications and patent applications are herein incorporated by reference to the same extent as if
10 each individual publication or patent application was specifically and individually indicated by reference.

EXAMPLES

Embodiments of the present invention are further defined in the following
15 non-limiting Examples. It should be understood that these Examples, while indicating certain embodiments of the invention, are given by way of illustration only. From the above discussion and these Examples, one skilled in the art can ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the
20 embodiments of the invention to adapt it to various usages and conditions. Thus, various modifications of the embodiments of the invention, in addition to those shown and described herein, will be apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims.

25 Equipment configuration and software were developed for on-site generation of peracid compositions, including peroxydicarboxylic acid forming compositions and peroxydicarboxylic acid for use as biocides. A reactor module meeting the hydraulic requirements of the reaction kinetics was developed to obtain precise and repeatable generation of active peracid chemistry. In addition, a software algorithm was
30 developed to run one or multiple reactor modules to sequence events appropriately to maximize active yield and safely operate the reactor module.

EXAMPLE 1

An exemplary single reaction vessel adjustable biocide formulator or
5 generator system is configured according to FIG. 2. In the single reactor model,
peroxyoctanoic acid and peroxyacetic acid were generated through the addition of
the sugar esters sorbitol octanoate and triacetin, respectively. The sugar esters were
added at different times to coordinate the completion of the hydrolysis reactions. In
the single reactor model the sugar esters are reacted in a single vessels, such that the
10 sugars are added according to reaction kinetics. For mixed peracid systems, an
exemplary multiple reaction vessel ABF configured according to FIGS. 3 or 4 was
used such that a second reactor module may be run in parallel.

The control software calculates the dosage and mix time and delay pump
sequencing so that both reactions to generate intermediates are completed at the
15 same time. Intermediates may be pumped to a third mix module before pumping to
a sump reservoir or dosing into the cleaning process.

For both single and/or mixed peracid systems, raw material feed times vary
according to the desired peracid system selected by a user or system controller input.
Raw materials may be dosed at the same time, in parallel to more than one reaction
20 vessel and/or sequentially to one or more reaction vessels of the ABF system.
Understanding when the perhydrolysis reaction starts is key to calculating reaction
time. For example; the reaction time starts when the pH of the reaction mixture is
increased through the addition of the caustic into the vessel and not when caustic
addition is finished. It is therefore advantageous to dose the caustic to the reaction
25 vessel as quickly as possible.

EXAMPLE 2

Adjustable biocide formulator system operating procedures for batch
30 *preparations.* A user or process controller input determines the desired peracid
formulation and volume to be generated on-site. Input information is loaded into the

formulator system. Formulator software calculates the time required to dose raw materials into reactor(s) and reaction time.

Upon set up, feed pumps are calibrated. Raw materials are fed to reaction vessel(s) and mixed in reaction vessel for a period of time for perhydrolysis reaction to take place. The extent of reaction is measured to determine when to quench a reaction with acid. Acid is either dosed into a reaction vessel at end of a mix period for short life intermediates or is dosed at a later time for longer lasting intermediates. The intermediates are pumped to a sump reservoir for dosing to a cleaning process or are dosed directly from reaction vessel into a cleaning process.

Adjustable biocide formulator system operating procedures for continuous preparations. A user or process controller input determines the desired peracid formulation and volume to be generated on-site in the continuous generator. Input information is loaded into the formulator system. Formulator software calculates the time required to dose raw materials into reactor(s) and reaction time.

Upon set up, feed pumps are calibrated. Raw materials are fed to reaction vessel(s) and mixed in reaction vessel for a period of time for perhydrolysis reaction to take place. The extent of reaction is measured to determine when to quench a reaction with acid. Acid is either dosed into the reaction manifold at the end of a mix period for short life intermediates or is dosed at a later time for longer lasting intermediates. Upon completion of the perhydrolysis reaction the intermediates may be pumped to a sump reservoir for dosing to a cleaning process or may be dosed directly from reaction vessel into a cleaning process. Beneficially the quenching reaction with the acid may take place within the reaction manifold or outside of the reaction manifold.

EXAMPLE 3

Titration of ABF Perhydrolysis Reactions

Duplicates						POOA				
Pera cid Type	Pera cid meas 'd	H ₂ O ₂ meas' d (wt %)	Total Av. O ₂ (w/w)	Vol Titrant Cons	Vol Titrant Consum ed EP2	Mol. Wt of Peraci d	Mol. Wt of H ₂ O ₂	Wt of Sample	Norm ality of Thio	Samp le volu me

	(% w/w)		(&)	umed EP1						
				(mL)	(mL)			(g)	(N)	(mL)
POO A	1.07	1.55	0.84	6.73	52.47	160	34	6.610	0.100	0.100
ABF 0832	1.09	1.58	0.85	6.23	48.69	160	34	6.000	0.100	0.100
pH 5.07	1.08	1.57	0.84							

- 5 *Samples were quenched with 6 mL of AcOH-100 per 100mL of fresh perhydrolysis/reaction solution. After AcOH quenching they were further diluted by the addition of 26g of NAS-Fal/106g of the above solution to homogenous the two phases quenched solutions. Therefore every reaction solution was diluted to 76% of its original activity and this was therefore built back into the calculations above thus the values displayed are the actual activities of the reaction solutions.

Duplicates						POOA				
Pera cid Type	Peraci d meas' d (% w/w)	H ₂ O ₂ meas' d (wt %)	Total Av. O ₂ (w/w &)	Vol Titrant Consum ed EP1	Vol Titrant Consum ed EP2	Mol. Wt of Peracid	Mol. Wt of H ₂ O ₂	Wt of Sample	Norma lity of Thio	Sam ple volu me
				(mL)	(mL)			(g)	(N)	(mL)
POO A	1.33	1.88	1.02	4.08	31.27	160	34	3.240	0.100	0.100
ABF 1035	1.34	1.87	1.01	4.05	30.62	160	34	3.180	0.100	0.100
pH 4.92	1.33	1.87	1.01							

Duplicates						POOA				
Pera cid Type	Peraci d meas' d (% w/w)	H ₂ O ₂ meas' d (wt %)	Total Av. O ₂ (w/w &)	Vol Titrant Consum ed EP1	Vol Titrant Consum ed EP2	Mol. Wt of Peracid	Mol. Wt of H ₂ O ₂	Wt of Sample	Norma lity of Thio	Sam ple volu me
				(mL)	(mL)			(g)	(N)	(mL)
POO A	1.26	1.85	1.00	3.90	31.00	160	34	3.270	0.100	0.100
ABF 1103	1.05	1.56	0.84	3.80	30.31	160	34	3.800	0.100	0.100
pH 4.96	1.15	1.71	0.92							

10

Sample	POOA%
0832	1.09
1035	1.34
1103	1.05
1325	1.10
1351	1.10
Ave	1.14

Stdev	0.12
RSD	10%

EXAMPLE 4

A study was performed to evaluate the ability to generate a mixed peroxycarboxylic acid composition in situ from ester starting materials at alkaline pHs. For this study, 1.28 grams of sorbitan octanoate, 14.68 grams of water, and 3.66 grams of a 35% hydrogen peroxide solution were added in a 100 mL beaker. With magnetic stirring, 14.64 grams of a 10% sodium hydroxide solution was added to the beaker. The solution was mixed for ten minutes. Then, 1.70grams of triacetin was added to the solution. After mixing for an additional five minutes, the solution was sampled to measure the peroxyacetic (POAA) and peroxyoctanoic (POOA) acid concentrations.

This two step addition process was also compared to a one step process. For the one step process, 1.26 grams of sorbitan octanoate, 1.70grams of triacetin, 14.67 grams o water, and 3.66 grams of a 35% hydrogen peroxide solution were added in a 100 mL beaker. With magnetic stirring, 14.64 grams of a 10% sodium hydroxide solution was added to the beaker. After mixing for 15 minutes, the solution was sampled for POAA and POOA levels. The results for both the two step and the one step reaction methods are shown in the table below.

TABLE 1

Reaction Process	Peroxyacetic Acid (wt%)	Peroxyoctanoic Acid (wt%)	Peroxyacetic/ Peroxyoctanoic (wt% as Peroxyacetic acid)	Temperature (maximum)	pH (initial – end)
Two Step	4.32	0.71	4.89	24.6°C	12.19 - 11.47
One Step	3.95	0.60	4.33	28.1°C	11.75 - 11.60

As can be seen from this table, the two step process delivered higher levels of POOA and POAA. It was also found that using the two step process described

above generated lower temperatures than the one step process. These lower temperatures are important from both a safety and a stability standpoint for this reaction. Without wishing to be bound by any particular theory, it is thought that in the two step process, the kinetically slower perhydrolysis reaction of sorbitan

5 octanoate was exposed to a more favorable perhydrolysis condition than in the one step reaction. That is in the two step process, the sorbitan octanoate is exposed to a higher pH and stoichiometrically more hydrogen peroxide. It is thought that these conditions contributed to the higher yield of POOA. Further, it is thought that the kinetically fast perhydrolysis reaction of triacetin was given enough perhydrolysis

10 reaction time, but avoided a prolonged exposure to a high pH condition, and thus achieved a better POAA yield.

EXAMPLE 5

15 Rheology of sugar esters. Rheology modifiers may optionally be included in the methods according to the present invention. Water soluble or water dispersible rheology modifiers that are useful can be classified as inorganic or organic. The organic thickeners can further be divided into natural and synthetic polymers with the latter still further subdivided into synthetic natural-based and synthetic

20 petroleum-based.

Additional experimentation demonstrates the best rheology of the ester to increase accuracy.

EXAMPLE 6

25 A series of experiments were conducted to determine the impact of the order of addition of reagents on the generation of peracid chemistry using the ABF generator according to the invention. The ABF generator according to the invention has demonstrate efficacy in the production of a peroxyoctanoic acid solutions

30 though combination of pre-cursor chemistries (e.g. ester premix with hydroxide and/or other activators) combined prior to having the reactants enter a reaction vessel. Surprisingly, an aspect of the invention involves the impact of reagent

addition order and dilution of the reagents on the generation of peracid chemistry. Aspects of the invention disclose preferred operating methods for generating a consist output (which is non-fouling) from the mixer and reaction vessel.

First, the ABF generator mixed reagents in the following order and design:

5 water, ester/peroxide, NaOH to form peracid. In particular, when the system was activated it injected water, ester/peroxide premix, and 50% caustic into a series of clear PVC injection manifolds that were plumbed together in series. The flow rate for all reagents entering the system was controlled at 25 g/min. Samples of the resultant mixture were collected at the exit of the solution and were titrated using an
10 iodometric titration procedure for peroxyoctanoic acid 10 minutes after the reagents were initially mixed. The resultant titration yielded a peracid concentration of approximately 1.75%. Based on the reagent formulation a POOA concentration of approximately 5.50% was expected. Upon evaluation of the mixing manifold it was apparent that a waxy solid was formed between the ester and NaOH injection ports,
15 providing a rationale for the low POOA titration. In particular, a poor mass transfer through the system resulted from the mix order of the reagents.

The second test order of ABF generator mixed reagents occurred nearly the same as the first example, with the exception that the injection points for the ester/peroxide premix and the NaOH were reversed. In particular, when the system
20 was activated it injected water, 50% caustic and an ester/peroxide premix into a series of clear PVC injection manifolds that were plumbed together in series. The results were the same as those outlined in the first example run of this Experiment 6, showing that under concentration conditions mixing order alone cannot overcome the fouling of the reagents.

25 The third example, tested the theory that the formation of the solid was a reaction between the concentrated ester and concentrated caustic. This was tested by combining 5 grams of glycerol octanoate with 5 grams of 50% NaOH in a 150 ml beaker. When the 2 materials were mixed they immediately formed a waxy solid that was very difficult to dissolve even in hot, approximately about 60°C (140°F)
30 water. This test confirmed the importance of dilute the caustic and/or sugar ester premix prior to reaction within the systems according to the invention.

A fourth test was conducted based on the results of the prior tests within this Example 6 to confirm whether an issue with the formation of the solid (e.g. fouled reagents) was poor dispersion of the ester/peroxide premix in the water prior to addition of the caustic. To alleviate this issue an injection manifold was re-designed to pre-mix the ester/peroxide solution with water prior to addition of the NaOH. In particular, an ester/peroxide premix is diluted and mixed within a static mixer prior to the addition of the caustic. Unexpectedly, the premixing of the ester/peroxide and water did not alleviate the precipitation issue (e.g. fouling of the reagents) as a precipitate still formed downstream from the addition of the NaOH. In addition, when titrating the solution a peracid concentration of POOA less than 1.0% was measured.

A fifth test was conducted. The order of addition of the reagents was further modified. In particular, the ester/peroxide premix and NaOH premix injection ports on the injection manifold were switched. In particular, when the system was activated it injected water and 50% caustic, prior to the addition of the ester/peroxide premix into the system. The outcome of this change in mix order of reagents was expected to generate similar or even poorer results relative to those from prior examples as this mixing profile would produce even less dispersion of ester/peroxide. Surprisingly, changing the order of addition had a marked effect on the reaction. Mixing the components in this manner produced a uniform output from the mixing manifold with no precipitation. In addition a sample of the peracid chemistry produced by this modified mixing system titrated a 5.46% peroxyoctanoic acid yield at 10 minutes after the chemistry precursors were combined.

The tests and results demonstrate the importance of the order of addition (e.g. diluted caustic followed by ester/peroxide premix).

EXAMPLE 7

A series of experiments were conducted to determine the impact of reagent concentration on the generation of peracid chemistry using the ABF generator according to the invention. In particular, the level of NaOH dilution to ensure uniform dispersion of the ester component was further analyzed. As set forth in

Table 2, 5 grams of a sugar ester were added to 5 grams of NaOH at varying concentrations - 50%, 25%, 20%, 15%, 12.5% and 6.25%. The reagents were added in test tubes with mild agitation. Production of precipitate in this test is an indication that the NaOH dilution is insufficient to produce a uniform output from this system.

TABLE 2

NaOH concentration	50%	25%	20%	15%	12.5%	6.25%
Ester/NaOH Rxn	White Solid	White Solid	White solid rapidly dissolves and disperses to a single phase	White solid rapidly dissolves and disperses to a single phase	Turbid single phase	Turbid single phase

10

The results shown in Table 2 demonstrate that the adjustable biocide formulator or generator system should deliver a NaOH solution that is no more than 20 wt-% on an actives basis before the ester component is combined with the NaOH to initiate the peracid production reaction.

15

EXAMPLE 8

A single peracid chemistry (POOA) having the formula set forth in Table 3A was prepared according to the methods and apparatus of the invention at two different flow rates as shown below in Table 3B.

Methods employed used a continuous generated having a reaction manifold as outlined in FIG. 7. In the continuous generation model, peroxyoctanoic acid was generated through the addition of the sugar ester sorbitol octanoate. The sugar ester was added to the oxidizing source, water and caustic for the hydrolysis reaction to occur at an alkaline pH (e.g. above about 12).

TABLE 3A

Formula	RM	Amt (%)
ABF POOA	Sorbitan Octanoate - diluted with 15% IPA	9.4%
	H ₂ O ₂ 35%	9.8%
	Soft water	72.0%
	NaOH 50% - rayon	8.8%
	Sum	100.0%

TABLE 3B

RM	low flow		High Flow	
	g/min	Wt %	g/min	Wt %
Sorbitan	6	7.2%	22	8.9%
35% Peroxide	5	6.0%	20	8.1%
Water	63	75.9%	180	72.7%
50% Caustic	9	10.8%	25.5	10.3%
Sum	83	100.0%	247.5	100.0%
Ave $\pm$ σ	2.76 $\pm$ 0.11		2.82 $\pm$ 0.07	

5

The results of the generation of a POOA chemistry using the methods and apparatus of the invention demonstrate that peroxyoctanoic acid (POOA) was prepared at approximately 2.8% concentration at two different flow rates (e.g. 83 g/min and 248 g/min). Beneficially, the apparatus and methods of the invention can be used to produce the same high concentration of desired chemistry at increased production rates, providing clear benefits from a production standpoint in order to satisfy a continuous and/or large volume demand for a particular peracid chemistry to be generated according to the invention.

15 The resultant peracid samples were analyzed using QATM 317: Suppressed Peroxide Titration for Peracids and Hydrogen Peroxide. Samples were not titrated for hydrogen peroxide.

EXAMPLE 9

20 A mixed peracid chemistry (POOA/POAA) having the formula set forth in Table 4A was prepared according to the methods and apparatus of the invention at a

higher flow rate as shown below in Table 4B. Table 4C shows the reaction time required for the generation each peracid in the mixed peracid chemistry generated.

Methods employed used a continuous generated having a reaction manifold as outlined in FIG. 7. In the continuous generation model, peroxyoctanoic acid and peroxyacetic acid were generated through the addition of the sugar ester sorbitol octanoate and triacetin. The sugar esters were added to the oxidizing source, water and caustic for the hydrolysis reaction to occur at an alkaline pH (e.g. above about 12). For the mixed peracid systems a single reaction manifold was employed (as opposed to a batch apparatus which may employ more than one reaction vessel or manifold). The dosage and mix time of the input reagents were controlled so that both reactions generated intermediates were completed at the same time. The raw starting material feed times varied to ensure the kinetics for the desired peracid system were achieved in a timely manner. As set forth according to the invention, understanding when the perhydrolysis reaction starts is key to calculating reaction time and the dosing of the raw starting materials (e.g. sugar esters). For example; the reaction time starts when the pH of the reaction mixture is increased through the addition of the caustic into the reaction manifold and not when caustic addition is finished.

TABLE 4A

Formula	RM	Amt (%)
ABF POOA/POAA	Sorbitan Octanoate	9.4%
	H ₂ O ₂ 35%	9.8%
	Soft water	72.0%
	NaOH 50% - rayon	8.8%
	Triacetin	3.5%
	Sum	100.0%

TABLE 4B

RM	High Flow	
	g/min	Wt %
Sorbitan	28	10.4%
35% Peroxide	21	7.8%
Water	183	68.3%

50% Caustic	27	10.1%
Triacetin	9	3.4%
Sum	268.0	100.0%

TABLE 4C

	Rxn Time	Wt %
POOA	8.4	2.82
POAA	1.1	2.58

- 5 The results show the production of a mixed peracid containing peroxyoctanoic acid (POOA) and peroxyacetic acid (POAA) at 2.8% and 2.6%, respectively, at a production rate of 268 g/min. The results confirm that either a peracid or mixed peracids can be prepared using the perhydrolysis of, for example, sorbitan octanoate and/or triacetin (sugar esters). Notably, additional sugar esters, including those disclosed herein (e.g. glyceryl octanoate) can be substituted the generation of a particular peracid chemistry.

10 The resultant peracid samples were analyzed using QATM 317: Suppressed Peroxide Titration for Peracids and Hydrogen Peroxide. Samples were not titrated for hydrogen peroxide. Determination of peroctanoic acid and peracetic acid in the mixed peracid sample was obtained by first generating the peroctanoic acid with the triacetin pump turned off and measuring the POOA concentration, sample A. The triacetin pump was then turned on and five minutes were allowed to enable the triacetin-containing mixture to reach the end of the flow manifold. The mixed peracid sample (B) was collected and titrated. The peracetic acid concentration was calculated as B-A.

EXAMPLE 10

25 The methods and apparatus according to the invention were tested to obtain increased percentage of peracid. Table 5 shows the peracid chemistry (POOA) generated according to the methods and apparatus of the invention. As shown titrated POOA produced was 5.7% and 5.8% within 5 minutes.

TABLE 5

30

	Formulation Proposed	Desired g/min	Measured g/min	Formulation Evaluated
Glycerol octanoate	14.67%	15.4	16	15.3%
35% HP	19.42%	20.4	22.8	21.8%
Water	49.17%	51.5	50	47.7%
50% NaOH	16.74%	17.5	16	15.3%
Sum	100.00	104.8	104.8	100%

The results confirm that peracid concentrated can be generated according to the perhydrolysis of sugar esters according to the invention in amounts exceeding those obtained from equilibrium reactions. In addition, the methods and apparatus
5 generate desired peracids rapidly.

EXAMPLE 11

A series of experiments were conducted to determine the impact of the order
10 of addition of reagents on the generation of peracid chemistry using the ABF generator according to the invention. The ABF generator according to the invention has demonstrate efficacy in the production of a peroxyoctanoic acid solutions though combination of pre-cursor chemistries (e.g. ester premix with hydroxide and/or other activators) combined prior to having the reactants enter a reaction
15 vessel. Surprisingly, an aspect of the invention involves the impact of reagent addition order and dilution of the reagents on the generation of peracid chemistry. Aspects of the invention disclose preferred operating methods for generating a consist output (which is non-fouling) from the mixer and reaction vessel.

First, the ABF generator mixed reagents in the following order and design:
20 water, ester/peroxide, NaOH to form peracid. In particular, when the system was activated it injected water, ester/peroxide premix, and 50% caustic into a series of clear PVC injection manifolds that were plumbed together in series. The flow rate for all reagents entering the system was controlled at 25 g/min. Samples of the resultant mixture were collected at the exit of the solution and were titrated using an
25 iodometric titration procedure for peroxyoctanoic acid 10 minutes after the reagents were initially mixed. The resultant titration yielded a peracid concentration of approximately 1.75%. Based on the reagent formulation a POOA concentration of

approximately 5.50% was expected. Upon evaluation of the mixing manifold it was apparent that a waxy solid was formed between the ester and NaOH injection ports, providing a rationale for the low POOA titration. In particular, a poor mass transfer through the system resulted from the mix order of the reagents.

- 5 The second test order of ABF generator mixed reagents occurred nearly the same as the first example, with the exception that the injection points for the ester/peroxide premix and the NaOH were reversed. In particular, when the system was activated it injected water, 50% caustic and an ester/peroxide premix into a series of clear PVC injection manifolds that were plumbed together in series. The results were the same as those outlined in the first example run of this Experiment 6, showing that under concentration conditions mixing order alone cannot overcome the fouling of the reagents.

- The third example, tested the theory that the formation of the solid was a reaction between the concentrated ester and concentrated caustic. This was tested by combining 5 grams of glycerol octanoate with 5 grams of 50% NaOH in a 150 ml beaker. When the 2 materials were mixed they immediately formed a waxy solid that was very difficult to dissolve even in hot (60°C) water. This test confirmed the importance of dilute the caustic and/or sugar ester premix prior to reaction within the systems according to the invention.

- 20 A fourth test was conducted based on the results of the prior tests within this Example 6 to confirm whether an issue with the formation of the solid (e.g. fouled reagents) was poor dispersion of the ester/peroxide premix in the water prior to addition of the caustic. To alleviate this issue an injection manifold was re-designed to pre-mix the ester/peroxide solution with water prior to addition of the NaOH. In particular, an ester/peroxide premix is diluted and mixed within a static mixer prior to the addition of the caustic. Unexpectedly, the premixing of the ester/peroxide and water did not alleviate the precipitation issue (e.g. fouling of the reagents) as a precipitate still formed downstream from the addition of the NaOH. In addition, when titrating the solution a peracid concentration of POOA less than 1.0% was measured.

A fifth test was conducted. The order of addition of the reagents was further modified. In particular, the ester/peroxide premix and NaOH premix injection ports on the injection manifold were switched. In particular, when the system was activated it injected water and 50% caustic, prior to the addition of the ester/peroxide premix into the system. The outcome of this change in mix order of reagents was expected to generate similar or even poorer results relative to those from prior examples as this mixing profile would produce even less dispersion of ester/peroxide. Surprisingly, changing the order of addition had a marked effect on the reaction. Mixing the components in this manner produced a uniform output from the mixing manifold with no precipitation. In addition a sample of the peracid chemistry produced by this modified mixing system titrated a 5.46% peroxyoctanoic acid yield at 10 minutes after the chemistry precursors were combined.

The tests and results demonstrate the importance of the order of addition (e.g. diluted caustic followed by ester/peroxide premix).

EXAMPLE 12

A series of experiments were conducted to determine the impact of reagent concentration on the generation of peracid chemistry using the ABF generator according to the invention. In particular, the level of NaOH dilution to ensure uniform dispersion of the ester component was further analyzed. As set forth in Table 6, 5 grams of a sugar ester were added to 5 grams of NaOH at varying concentrations - 50%, 25%, 20%, 15%, 12.5% and 6.25%. The reagents were added in test tubes with mild agitation. Production of precipitate in this test is an indication that the NaOH dilution is insufficient to produce a uniform output from this system.

TABLE 6

NaOH concentration	50%	25%	20%	15%	12.5%	6.25%
Ester/NaOH Rxn	White Solid	White Solid	White solid rapidly	White solid rapidly	Turbid single phase	Turbid single phase

			dissolves and disperses to a single phase	dissolves and disperses to a single phase		
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The results shown in Table 6 demonstrate that the adjustable biocide
formulator or generator system should deliver a NaOH solution that is no more than
5 20 wt-% on an actives basis before the ester component is combined with the NaOH
to initiate the peracid production reaction.

EXAMPLE 13

A single peracid chemistry (POOA) was generated using an ABF generator
10 according to an embodiment of the invention using the reagents set forth in Table
7A.

TABLE 7A

Reagent Formula		Amt (%)
ABF POOA	Glycerol Octanoate	14.67%
	H ₂ O ₂ 35%	19.42%
	Water	49.44%
	NaOH 50%	16.47%

15 POOA production rates were generated as a function of reagents and
generator temperatures. A continuous ABF generator was used wherein both the
reagent and reaction vessels temperature were controlled with a heating/cooling
water bath as set forth in Table 7B. The results demonstrate the POOA production as
20 a function of time.

TABLE 7B

5 °C Rxn		20 °C Rxn		30 °C Rxn		40 °C Rxn	
time	%POOA 5°C	time	%POOA 20°C	Time	%POOA 30°C	time	%POOA 40°C
10	2.55	1	2.07	1		1	5.19
20	3.45	5	3.89	3	4.56	3	6.23
30	3.90	10	4.77	5	5.24	5	6.06

40	4.20	15	5.46	10	6.35	7	5.36
50	4.20	20	5.83	15	6.57	10	5.40
60	4.50	25	6.30	20	6.52	15	3.38
70	4.72	30	6.67	30	6.29	20	3.82
		40	6.77	45	5.60		
		50	6.73	90	4.36		
		70	6.61				
		90	6.36				
		160	5.66				

The results are shown in FIG. 11 (graphical representation of POOA concentration over time at various reaction temperatures). The graph confirms that under different environmental temperatures the concentration of available peracid is widely variable. The variability depends upon the temperature of the generator and temperature of the reactants (e.g. raw starting materials) and of the time point at which the reaction mixture would be used. These results demonstrate the importance of mechanisms for controlling the ex-situ peracid reaction temperature of the reaction vessel or reaction manifold (i.e. regardless of whether batch and/or continuous generation apparatus and/or methods are used according to the invention). The control of temperature impacts the kinetics of the reaction and therefore can be critical to consistency of peracid output according to the invention.

EXAMPLE 14

Methods of thermal control were analyzed. The reaction rates of a single peracid chemistry (POOA) generated using an ABF generator according to an embodiment of the invention were analyzed. The reagents set forth in Table 8A were used to generate POOA. The test utilized reactants that were stored at either 5°C or 40°C (as further shown in Table 8B) to represent the changes in (and ranges of) temperatures one skilled in the art may expect in practice.

TABLE 8A

Reagent Formula		Amt (%)
ABF POOA	Glycerol Octanoate	9.83%

	H ₂ O ₂ 35%	13.02%
	Water (21°C)	65.90%
	NaOH 50%	11.21%

The test used a jacket to cover the reaction vessel of the ABF generator to control the temperature of the reagents. In the testing a batch ABF generator was employed (however the same tested methods can be employed for a continuous generator as disclosed pursuant to the invention). The temperature was controlled to 20°C (~69°F). In this reaction the glycerol octanoate, peroxide and water reagents (e.g. raw starting materials) were added to the reaction vessel first. Once those ingredients were combined the 50% NaOH was added. For purposes of testing this reaction scheme was utilized as a result of the addition of NaOH both initiating the reaction and causing a large exothermic effect. Both temperature and resultant peracid were monitored in this reaction.

POOA production rates and temperature were monitored as a function of time with reaction vessel temperatures controlled to 20°C, wherein the reagents were stored at either 5°C or 40°C. The results are shown in Table 8B.

TABLE 8B

time (min)	temp with 5°C reagents	temp with 40°C reagents	POOA @ 5°C	POOA @ 40°C
0	69	84	0	0
1	80	84	0.73	0.95
3	72	73	1.36	1.58
5	70	71	1.69	1.90
10	69	69	2.28	2.44
20	69	69	2.80	3.04
30	69	69	3.22	3.50
45	69	69	3.72	3.98
60	69	69	4.02	4.24
90	69	69	4.30	4.23
120	69	69	4.03	4.00
180	69	69		3.57

The results are further shown in the graph of FIG. 12. The identified time period from approximately 50 minutes to 120 minutes (shown in the boxed area of the graph) outlines where the 2 separate reaction mixtures (one with reagents starting at 5°C and one with reagents starting at 40°C) achieved maximum percentage POOA generation. These results demonstrate the ability to use temperature control as a means of driving toward consistency in the chemistry output of an ex-situ peracid generator without regard to environmental temperatures.

This example required increased time to achieve maximum generation of the peracid chemistry, notably about 50 minutes to achieve the +/- 10% max target for peracid generation. However, as one skilled in the art of chemical reaction kinetics will ascertain, to decrease the time period for achieving maximum peracid generation the temperature of the reaction vessel and/or reaction manifold can be increased.

EXAMPLE 15

Additional methods of thermal control were analyzed. The thermal control scheme outlined in Example 14 may add cost and/or complexity to an ABF system. As a result, improvements to the various methods for including temperature control for a reaction vessel and/or reaction manifold were analyzed. An alternative was evaluated - heating one or more of the raw starting materials (i.e. reagents) for the ex-situ peracid composition. The heating of reagents as opposed to the reaction vessel and/or reaction manifold was evaluated as a means to control the reaction kinetics in the ABF system.

In this analysis water was selected as the raw starting material that was temperature controlled. Water was selected based on the fact that water tends to be the most abundant reagent in many peracid recipes according to the invention. In addition, the heating of water can be easily and inexpensively achieved as one skilled in the art will appreciate.

The reagents set forth in Table 9A were used to generate POOA.

TABLE 9A

Reagent Formula		Amt (%)
ABF POOA	Glycerol Octanoate	9.83%
	H ₂ O ₂ 35%	13.02%
	Water	65.90%
	NaOH 50%	11.21%

Table 9B shows the POOA production rates and temperature as a function of time with reagent temperatures controlled to variable temperatures - 5°C and 40°C, as opposed to temperature control of the reaction vessel and/or reaction manifold. The results are shown in Table 9B.

TABLE 9B

time (min)	POOA 5°C reagents	POOA 40°C reagents	Rxn Temp 5°C reagents	Rxn Temp 40°C reagents
0	0	0	89	94
1	1.26	1.65	109	117
3	2.30	2.68	106	112
5	2.82	3.16	103	108
10	3.56	3.65	96	100
15	3.70	3.87	85	94
20	3.83	3.83	87	89
30	3.92	3.76	80	81
45	3.90	3.63	74	75
60	3.80	3.52	72	72
90	3.62		72	

The results are further shown in the graph of FIG. 13. The results demonstrate the potential to use a heated water source to produce reaction kinetic rates in in ex-situ peracid generator through the use of a heated water source with no other temperature control in the ABF system.

EXAMPLE 16

Examples 13-15 highlight the importance of using warm water to control reaction rate and stability. Example 16 in contrast outlines an situation where a cooler temperature is preferred to both control reaction rate and stabilize the peracid that is formed.

- 5 The reagents set forth in Table 10A were used to generate POAA in a bench top experiment @ ambient environmental temperatures ~ 70°F (~21°C)

TABLE 10A

Reagent Formula		Amt (%)
ABF POAA	Triacetin	6.0%
	H ₂ O ₂ 50%	11.2%
	Water	79.8%
	NaOH 50%	3.0%

- 10 Table 10B shows the POAA production rates and temperature as a function of time using water in the reaction that was preheated to 104°F (40°C).

TABLE 10B

Time (min)	Rxn Temp. (degrees F) 104°F water	% POAA
0	96	
1	110	2.41
2	112	2.25
3	113	1.99
4	113	1.77
5	113	1.58
10	112	0.83

- 15 Table 10C in contrast show the same reaction scheme using 38°F (~3.3°C) water

TABLE 10C

time (min)	Rxn Temp. (degrees F) 38°F water	POAA
0	46	
1	56	2.22
3	58	2.49
5	60	2.52
10	64	2.44
15	67	2.36

The key difference in these reactions is not in yield, as both compositions develop a maximum concentration of ~2.5% POAA. The critical difference comes down to the stability of the resultant reaction and the ability to maintain a +/- 10% max POAA window with the use of cooler than ambient water in this reaction

5 scheme.

The inventions being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the inventions and all such modifications are intended to be

10 included within the scope of the following claims.

Claims:

1. An adjustable biocide formulator or generator system for on-site peroxycarboxylic acid forming composition generation comprising:
- 5 an apparatus comprising at least one reaction vessel, a series of feed pumps and an outlet
- for dosing a peroxycarboxylic acid forming composition from said reaction vessel;
- wherein said feed pumps are in fluid connection with said reaction vessel and supply
- 10 reagents to produce said peroxycarboxylic acid forming composition in said reaction vessel;
- wherein said reagents comprise an ester of a polyhydric alcohol and a C1 to C18 carboxylic acid, a source of alkalinity and an oxidizing agent;
- wherein said reaction vessel is in fluid connection with said outlet to dispense said
- 15 peroxycarboxylic acid forming composition; and
- wherein said peroxycarboxylic acid forming composition is an individual or mixed peroxycarboxylic acid forming composition according to a user- or system-inputted selection.
- 20 2. An adjustable biocide formulator or generator system for on-site peroxycarboxylic acid forming composition generation comprising:
- an apparatus comprising a variable length of a reaction manifold, a series of feed pumps
- and an outlet for dosing a peroxycarboxylic acid forming composition from
- 25 said reaction manifold;
- wherein said reaction manifold is a length of tubing having multiple points of input via
- at least one injection manifold wherein said feed pumps provide said reagents for
- 30 the continuous production of said peroxycarboxylic acid forming composition;

- wherein said feed pumps are in fluid connection with said reaction manifold and supply
- one or more reagents to produce said peroxycarboxylic acid forming composition in said reaction manifold;
- 5 wherein said reagents comprise an ester of a polyhydric alcohol and a C1 to C18 carboxylic acid, a source of alkalinity and an oxidizing agent; wherein said reaction manifold is in fluid connection with said outlet to dispense said
- peroxycarboxylic acid forming composition; and
- 10 wherein said peroxycarboxylic acid forming composition is an individual or mixed peroxycarboxylic acid forming composition according to a user- or system-inputted selection.
3. The system according to claims 1 or 2, wherein the source of alkalinity is
- 15 sodium hydroxide (e.g. caustic soda), and wherein said sodium hydroxide is provided to said reaction vessel prior to the addition of said ester in a solution that is less than about 20 wt-% sodium hydroxide on an actives basis.
4. The system according to claims 1 or 2, further comprising at least one
- 20 measurement device, wherein said measurement device measures one or more reaction kinetics or system operations for said peroxycarboxylic acid forming composition generation selected from the group consisting of fluorescence, weight, flow, capacitive level, pH, oxidation reduction potential, pressure, temperature and combinations thereof.
- 25
5. The system according to claim 1, wherein said ester and other reagents are fed to said reaction vessel or reaction manifold to produce a single peroxycarboxylic acid forming composition, and wherein said ester is selected from the group consisting of monooctanoic glyceride, dioctanoic glyceride, trioctanoic glyceride,
- 30 sorbitan monooctanoate, sorbitan dioctanoate, sorbitan trioctanoate, laurate sucroside and mixtures and derivatives thereof.

6. The system according to claim 2, wherein more than one ester is added with said other reagents to said reaction manifold sequentially or in parallel to produce a mixed peroxycarboxylic acid forming composition, wherein said ester is selected from the group consisting of monooctanoic glyceride, dioctanoic glyceride,
5 trioctanoic glyceride, sorbitan monooctanoate, sorbitan dioctanoate, sorbitan trioctanoate, laurate sucroside and mixtures and derivatives thereof

7. The system according to claim 1, wherein more than one ester is added with said other reagents to a single reaction vessel or separate reaction vessels
10 sequentially or in parallel to produce a mixed peroxycarboxylic acid forming composition, wherein said ester is selected from the group consisting of monooctanoic glyceride, dioctanoic glyceride, trioctanoic glyceride, sorbitan monooctanoate, sorbitan dioctanoate, sorbitan trioctanoate, laurate sucroside and mixtures and derivatives thereof.

15 8. The system according to claim 2, wherein more than one ester is added with said other reagents to said reaction manifold sequentially or in parallel to produce a mixed peroxycarboxylic acid forming composition, wherein said ester is selected from the group consisting of monooctanoic glyceride, dioctanoic glyceride,
20 trioctanoic glyceride, sorbitan monooctanoate, sorbitan dioctanoate, sorbitan trioctanoate, laurate sucroside and mixtures and derivatives thereof

9. The system according to claims 1 or 2, wherein said apparatus further comprises a
25 reservoir in fluid connection with said reaction vessel outlet to mix or store said peroxycarboxylic acid forming compositions from said reaction vessel or reaction manifold.

10. The system according to claim 9, further comprising an additional feed pump
30 providing an acid or acidic aqueous solution in fluid communication with said reaction vessel or reaction manifold or said reservoir, wherein said acid or acidic

aqueous solution dilutes said peroxydicarboxylic acid forming composition to form a peroxydicarboxylic acid having a pH of about 1.0 to about 8.0.

11. The system according to claim 1, further comprising mixers, circulation
5 pumps,
holding vessels, reagent delivery sensors or combinations of the same.
12. The system according to claims 1 or 2, further comprising a control software
for
10 operating said apparatus to generate a user- or system-inputted peroxydicarboxylic
acid forming composition and desired volume of said peroxydicarboxylic acid forming
composition for on-site generation.
13. The system according to claim 12, wherein said control software determines
15 the
timing of feeding said raw materials to said reaction vessel or reaction manifold,
mixing and reaction time required for production of said user- or system-inputted
peroxydicarboxylic acid forming composition and desired volume.
- 20 14. The system according to claim 1, wherein said ester is traicetin or sorbitan
octanoate, wherein said oxidizing agent comprises a hydrogen peroxide donor, and
wherein said the source of alkalinity is selected from the group consisting of an
alkaline metal hydroxide, an alkaline earth metal hydroxide, an alkali metal silicate,
an alkali metal carbonate, borates and mixtures thereof.
- 25 15. The system according to claims 1 or 2, further comprising a data output
means for
sharing information related to said peroxydicarboxylic acid forming composition
formulation, peroxydicarboxylic acid forming composition consumption or usage,
30 additional peroxydicarboxylic acid forming composition production-related data or
combinations of the same.

16. A method for on-site peroxydicarboxylic acid forming composition generation or peroxydicarboxylic acid generation comprising:
inputting a user- or system-controlled peroxydicarboxylic acid forming composition or
5 peroxydicarboxylic acid formulation into a control software for an adjustable biocide formulator or generator system, wherein said input formulation selects an individual or mixed peroxydicarboxylic acid forming composition or peroxydicarboxylic acid and corresponding volume or mass for on-site generation; and
10 mixing one or more sugar esters of a polyhydric alcohol and a C1 to C18 dicarboxylic acid, a source of alkalinity and an oxidizing agent at alkaline pH in the adjustable biocide formulator or generator system of claim 1 at a pH above at least 12.
- 15 17. A method for on-site peroxydicarboxylic acid forming composition generation or peroxydicarboxylic acid generation comprising:
inputting a user- or system-controlled peroxydicarboxylic acid forming composition or
20 peroxydicarboxylic acid formulation into a control software for a continuous adjustable biocide formulator or generator system, wherein said input formulation selects an individual or mixed peroxydicarboxylic acid forming composition or peroxydicarboxylic acid and corresponding volume or mass for continuous on-site generation; and
25 combining one or more sugar esters of a polyhydric alcohol and a C1 to C18 dicarboxylic acid, a source of alkalinity and an oxidizing agent at alkaline pH in the adjustable biocide formulator or generator system of claim 1 at a pH above at least 12.
- 30 18. The method according to claims 16 or 17, wherein the source of alkalinity is sodium hydroxide (e.g. caustic soda), and wherein said sodium hydroxide is

provided to said reaction vessel prior to the addition of said ester in a solution that is less than about 20 wt-% sodium hydroxide on an actives basis.

19. The method according to claim 18, wherein said sodium hydroxide is diluted
5 with water to the target concentration of less than about 20 wt-% within the system and prior to the addition of said ester.

20. The method according to claims 16 or 17, wherein said input is a user or a
system
10 selecting a peroxycarboxylic acid or peroxycarboxylic acid forming composition, wherein said system is selected from the group consisting of a CIP process, bottle washer, aseptic filler, vegetable wash or rinse sink, 3rd sink sanitizing sink, textile bleaching process and combinations thereof.

15 21. The method according to claim 20, wherein said user or a system input further selects a single or multiple reaction vessel mode for peroxycarboxylic acid and/or mixed peroxycarboxylic acid or peroxycarboxylic acid forming composition generation.

20 22. The method according to claim 17 further comprising timing the addition of said esters in parallel or sequentially for reaction in said reaction manifold.

25 23. The method according to claim 16 further comprising timing the addition of said esters in parallel or sequentially for reaction in a single reaction vessel or separate reaction vessels, and combining peroxycarboxylic acid forming compositions from separate reaction vessels into an additional reaction vessel or a reservoir.

30 24. The method according to claims 16 or 17, further comprising measuring the extent of said ester perhydrolysis reaction using one or more measurement devices,

wherein said measurement device measures one or more reaction kinetics or system operations for said peroxy-carboxylic acid generation selected from the group consisting of fluorescence, weight, flow, capacitive level, pH, oxidation reduction potential, pressure, temperature and combinations thereof.

5

25. The method according to claim 24, wherein said measurement devices determine when to dilute said peroxy-carboxylic acid forming composition with an acid or aqueous acidic solution to form said peroxy-carboxylic acid.

10

26. The method according to claims 16 or 17, further comprising providing an acid or aqueous acidic solution to form a peroxy-carboxylic acid having a pH of about 1.0 to about 8.0.

15

27. The method according to claims 16 or 17, further comprising dispensing said peroxy-carboxylic acid forming composition for use in a cleaning process.

28. The method according to claim 16, wherein said mixing step takes place in said reaction vessel using a mechanical blade mixer having a variable speed control motor to achieve homogeneous blending of reagents.

20

29. A method of cleaning using an on-site generated peroxy-carboxylic acid forming composition comprising:
obtaining a user- or system-inputted peroxy-carboxylic acid forming composition on-site

25

using the adjustable biocide formulator or generator system of claim 1;
applying said peroxy-carboxylic acid forming composition in an amount sufficient to sanitize, bleach and/or disinfect a surface in need thereof.

30

30. A method of cleaning using an on-site generated peroxy-carboxylic acid forming composition comprising:

obtaining a user- or system-inputted peroxydicarboxylic acid forming composition on-site

using the adjustable biocide formulator or generator system of claim 2; and
applying said peroxydicarboxylic acid forming composition in an amount sufficient to

5 sanitize, bleach and/or disinfect a surface in need thereof.

31. A method for on-site, temperature controlled peroxydicarboxylic acid forming composition generation or peroxydicarboxylic acid generation comprising:

inputting a user-desired or system-controlled peroxydicarboxylic acid forming

10 composition or peroxydicarboxylic acid formulation into a control software for on-site generation, wherein said input formulation selects an individual or mixed peroxydicarboxylic acid forming composition or peroxydicarboxylic acid and corresponding volume or mass for on-site generation; and

combining one or more esters of a polyhydric alcohol and a C1 to C18 dicarboxylic

15 acid, a source of alkalinity and an oxidizing agent at alkaline pH in an adjustable biocide formulator or generator system at a pH above at least 12, wherein said system is an apparatus that is insensitive to environmental temperatures of the location of the apparatus and/or reagents comprising a reaction vessel, a series of feed pumps, an outlet for dosing a

20 peroxydicarboxylic acid forming composition from said reaction vessel and a controller for a user- or system-inputted selection device; and

generating a peroxydicarboxylic acid forming composition or peroxydicarboxylic acid formulation;

25 wherein said temperature insensitivity to the environmental temperatures of the location of

the apparatus and/or reagents is controlled by a mechanism for maintaining a controlled temperature of said reaction vessel and/or one or more reagents;

wherein said feed pumps are in fluid connection with said reaction vessel and supply one or more reagents to produce said peroxydicarboxylic acid forming

30 composition in said reaction vessel; and

wherein said reaction vessel is in fluid connection with said outlet to dispense said peroxydicarboxylic acid forming composition.

32. The method according to claim 31, wherein the temperature control of said reaction vessel and supply of said reagents adjusts to a temperature of between about 4.4°C to about 60°C.
- 5
33. The method according to claim 32, wherein said temperature is adjusted to between about 21°C to about 49°C.
34. The method according to claim 31, wherein the source of alkalinity is sodium hydroxide (e.g. caustic soda), and wherein said sodium hydroxide is provided to said reaction vessel prior to the addition of said ester in a diluted solution.
- 10
35. The method according to claim 31, wherein the peroxycarboxylic acid forming composition reaction goes to completion within less than about 30 minutes.
- 15
36. The method according to claim 31, wherein the peroxycarboxylic acid forming composition maintains a peracid concentration within about 10% of its final completion concentration for at least about 1 minute.
- 20
37. The method according to claim 31, wherein said temperature control mechanism is selected from the group consisting of external heating or cooling of the reaction vessel, internal heating of the reagents within the reaction vessel, preheating one or more of the reagents, and combinations of the same.
- 25
38. The method according to claim 37, wherein said reaction vessel is a flow through reactor (e.g. continuous generation) or a batch reactor and the heated reagent is water.
- 30
39. The method according to claim 31, further comprising timing the addition of said

esters in parallel or sequentially for reaction in said reaction manifold.

40. The method according to claim 31, further comprising measuring the extent of

5 said ester perhydrolysis reaction using one or more measurement devices, wherein said measurement device measures one or more reaction kinetics or system operations for said peroxycarboxylic acid generation selected from the group consisting of fluorescence, weight, flow, capacitive level, pH, oxidation reduction potential, pressure, temperature and combinations thereof, and wherein said
10 measurement devices determine when to dilute said peroxycarboxylic acid forming composition with an acid or aqueous acidic solution to form said peroxycarboxylic acid.

41. The method according to claim 31, further comprising providing an acid or
15 aqueous acidic solution to form a peroxycarboxylic acid having a pH of about 0.1 to about 8.0, wherein the neutralization with the acid or aqueous acidic solution takes place when the concentration of peracid is within about 10% of its final concentration.

20 42. The method according to claim 31, further comprising dispensing said peroxycarboxylic acid forming composition for use in a cleaning process, wherein said composition is dispensed from said reaction vessel when the concentration of peracid is within about 10% of its final concentration.

25 43. A temperature controlled adjustable biocide formulator or generator system for on-site peroxycarboxylic acid forming composition generation comprising: an apparatus for producing peroxycarboxylic acid forming composition that is insensitive

30 to environmental temperatures of the location of the apparatus and/or reagents comprising a reaction vessel, a series of feed pumps, an outlet for dosing a

peroxycarboxylic acid forming composition from said reaction vessel and a controller for a user- or system-inputted selection device;
a temperature controlled mechanism for maintaining a controlled temperature of said reaction vessel and/or one or more reagents to a temperature between about
5 4.4°C to about 60°C, wherein said reagents comprise an ester of a polyhydric alcohol and a C1 to C18 carboxylic acid, a source of alkalinity and an oxidizing agent;
wherein said feed pumps are in fluid connection with said reaction vessel and supply one or more reagents to produce said peroxycarboxylic acid forming
10 composition in said reaction vessel; and
wherein said reaction vessel is in fluid connection with said outlet to dispense said peroxycarboxylic acid forming composition.

44. The system according to claim 43, wherein said temperature is adjusted to
15 between about 21°C to about 49°C.

45. The system according to claim 43, wherein the source of alkalinity is sodium hydroxide (e.g. caustic soda), and wherein said sodium hydroxide is provided to said reaction vessel prior to the addition of said ester in a diluted solution.
20

46. The system according to claim 43, further comprising at least one measurement device, wherein said measurement device measures one or more reaction kinetics or system operations for said peroxycarboxylic acid forming composition generation selected from the group consisting of fluorescence, weight,
25 flow, capacitive level, pH, oxidation reduction potential, pressure, temperature and combinations thereof.

47. The system according to claim 43, wherein the peroxycarboxylic acid forming composition reaction goes to completion within less than about 30 minutes
30 and maintains a peracid concentration within about 10% of its final completion concentration for at least about 1 minute.

48. The system according to claim 43, wherein said temperature control mechanism is selected from the group consisting of external heating or cooling of the reaction vessel, internal heating of the reagents within the reaction vessel,
5 preheating one or more of the reagents, and combinations of the same.

49. The system according to claim 48, wherein said reaction vessel is a flow through reactor (e.g. continuous generation) or a batch reactor and the heated reagent is water.

10

50. The system according to claim 43, wherein said apparatus further comprises a reservoir in fluid connection with said reaction vessel outlet to mix or store said peroxydicarboxylic acid forming compositions from said reaction vessel.

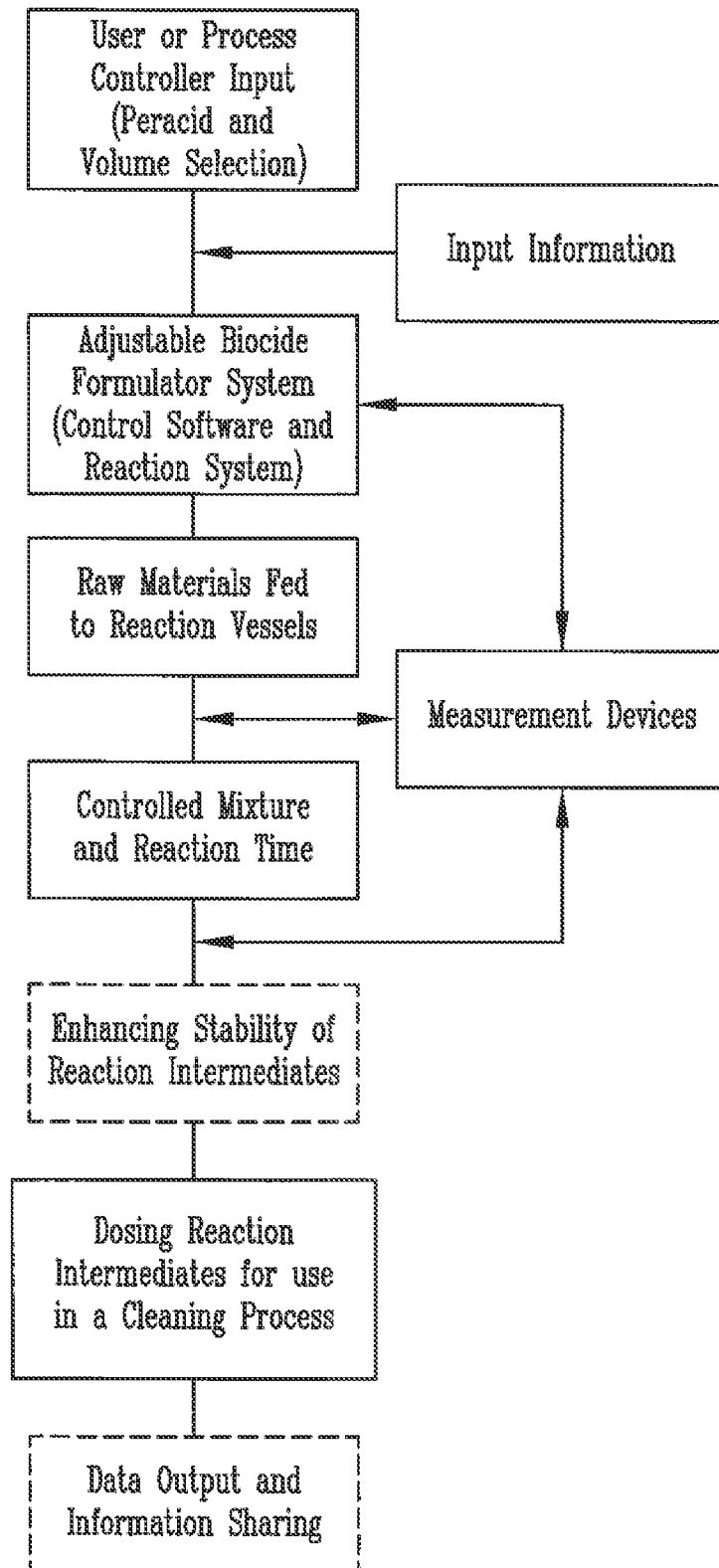
15

51. The system according to claim 43, further comprising an additional feed pump providing an acid or acidic aqueous solution in fluid communication with said reaction manifold or said reservoir, wherein said acid or acidic aqueous solution
20 dilutes said peroxydicarboxylic acid forming composition to form a peroxydicarboxylic acid having a pH of about 0.1 to about 8.0, wherein the neutralization with the acid or aqueous acidic solution takes place when the concentration of peracid is within about 10% of its final concentration.

25 52. The system according to claim 43, further comprising a control software for operating said apparatus to generate a user- or system-inputted peroxydicarboxylic acid forming composition and desired volume of said peroxydicarboxylic acid forming composition for on-site generation, and wherein said control software determines the timing of feeding said raw materials to said reaction manifold, mixing and reaction
30 time required for production of said user- or system-inputted peroxydicarboxylic acid forming composition and desired volume.

53. The system according to claim 43, further comprising a data output means for sharing information related to said peroxydicarboxylic acid forming composition formulation, peroxydicarboxylic acid forming composition consumption or usage,
5 additional peroxydicarboxylic acid forming composition production-related data or combinations of the same.

54. A method of cleaning using an on-site generated peroxydicarboxylic acid forming composition comprising:
10 obtaining a user- or system-inputted peroxydicarboxylic acid forming composition on-site
using the adjustable biocide formulator or generator system of claim 43; and
applying said peroxydicarboxylic acid forming composition in an amount sufficient to
sanitize, bleach and/or disinfect a surface in need thereof,
15 wherein said composition retains within about 10% of its final concentration of peracid for at least about 1 minute.

1/15**Fig. 1**

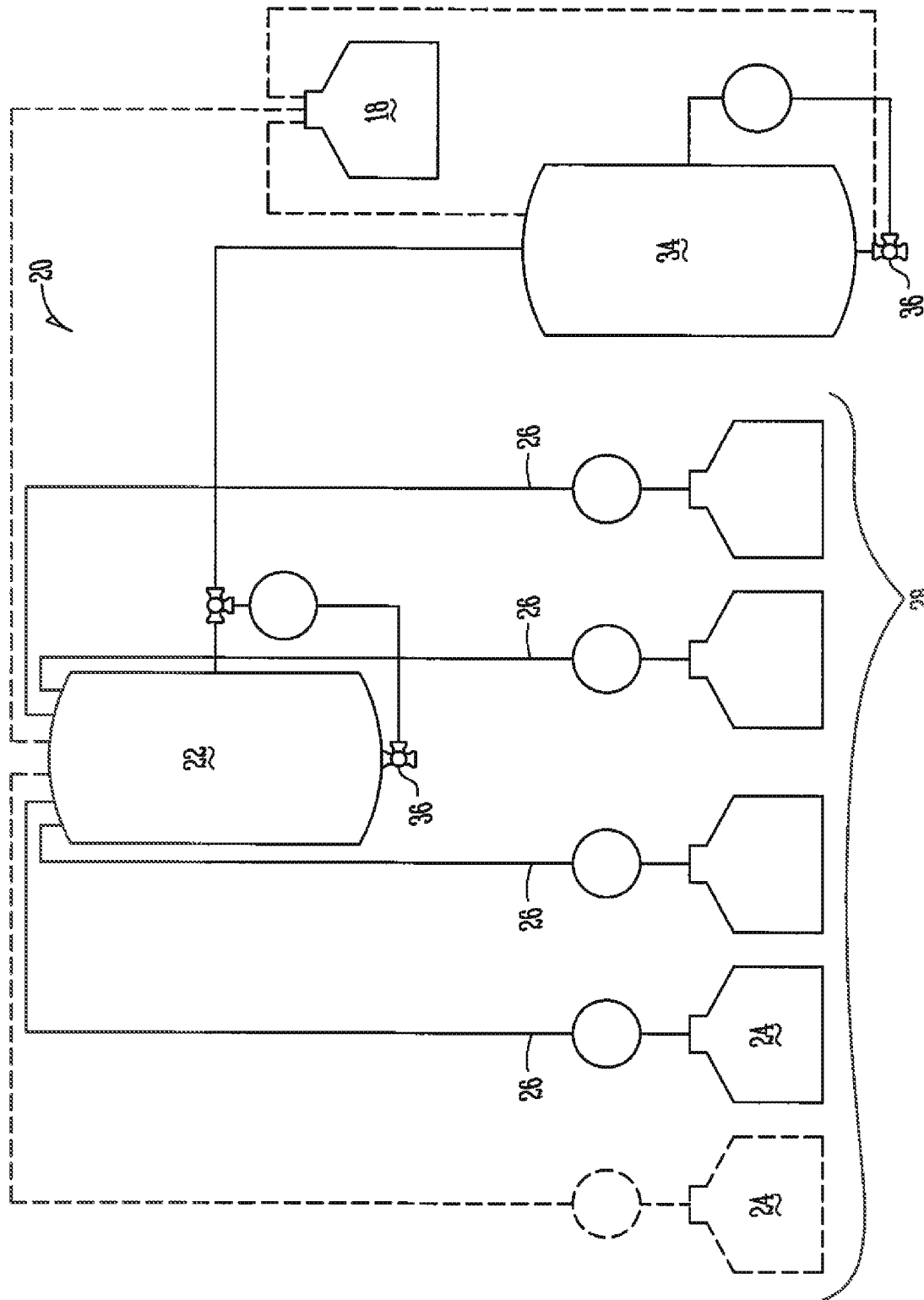
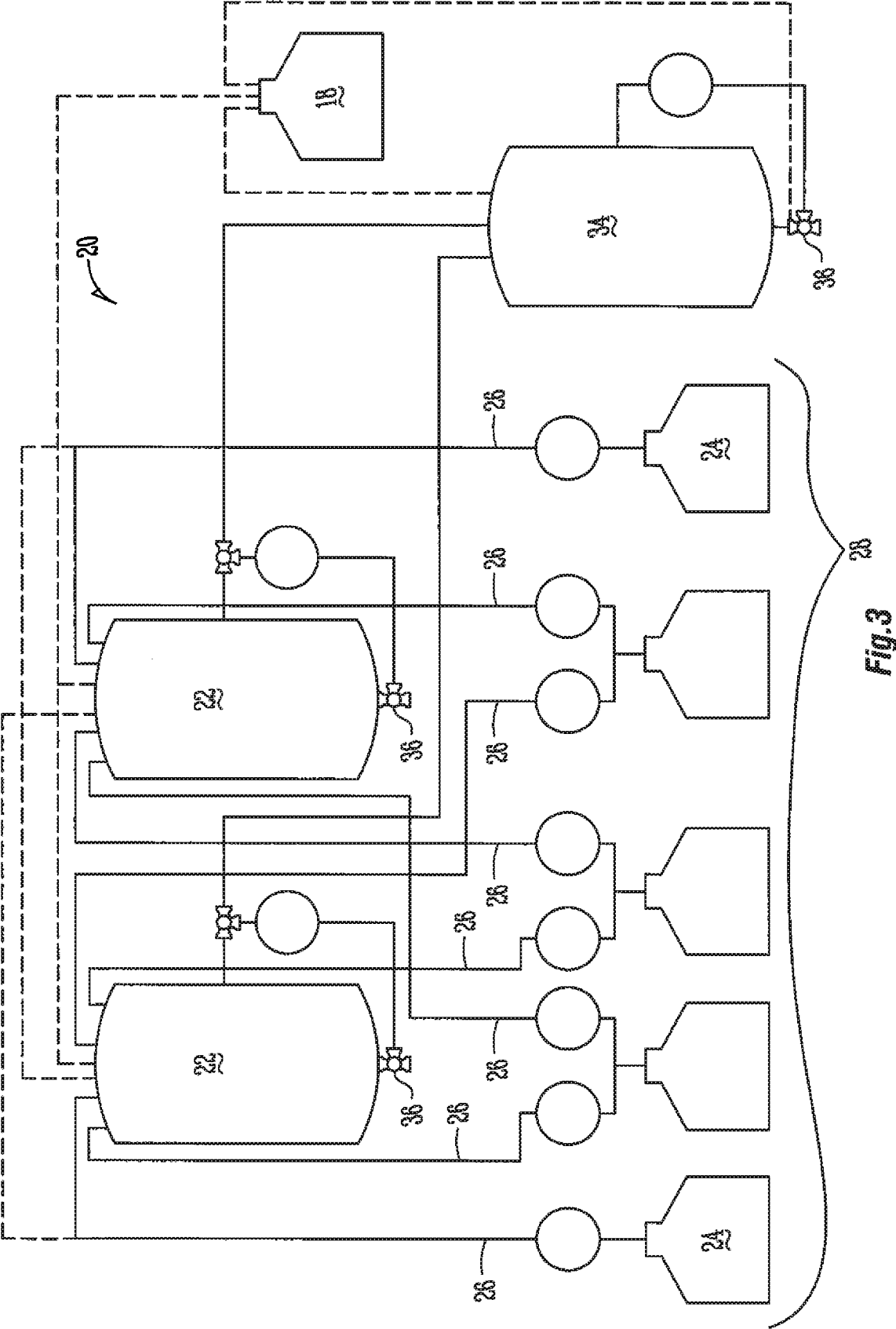


Fig.2



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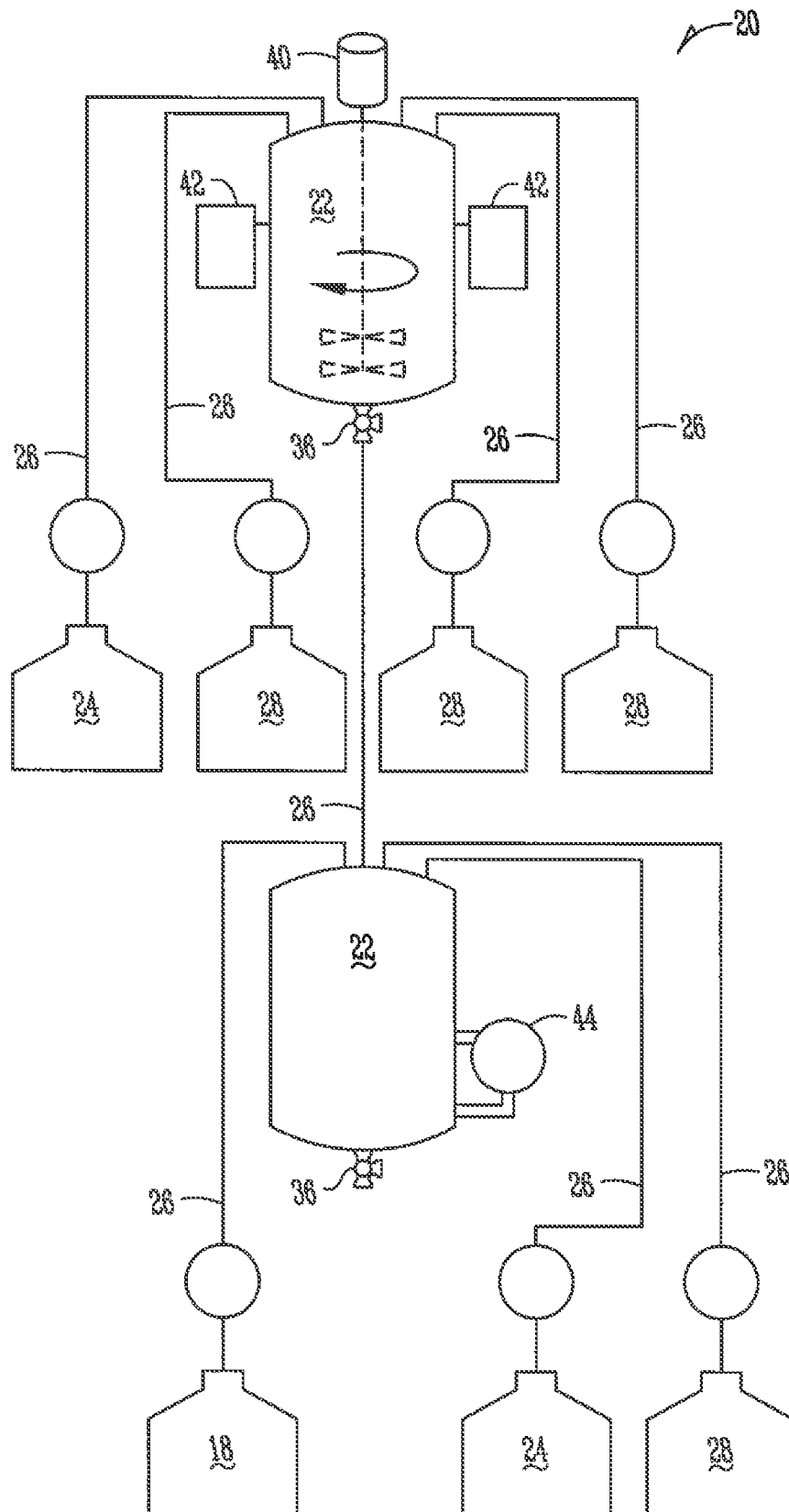


Fig.4

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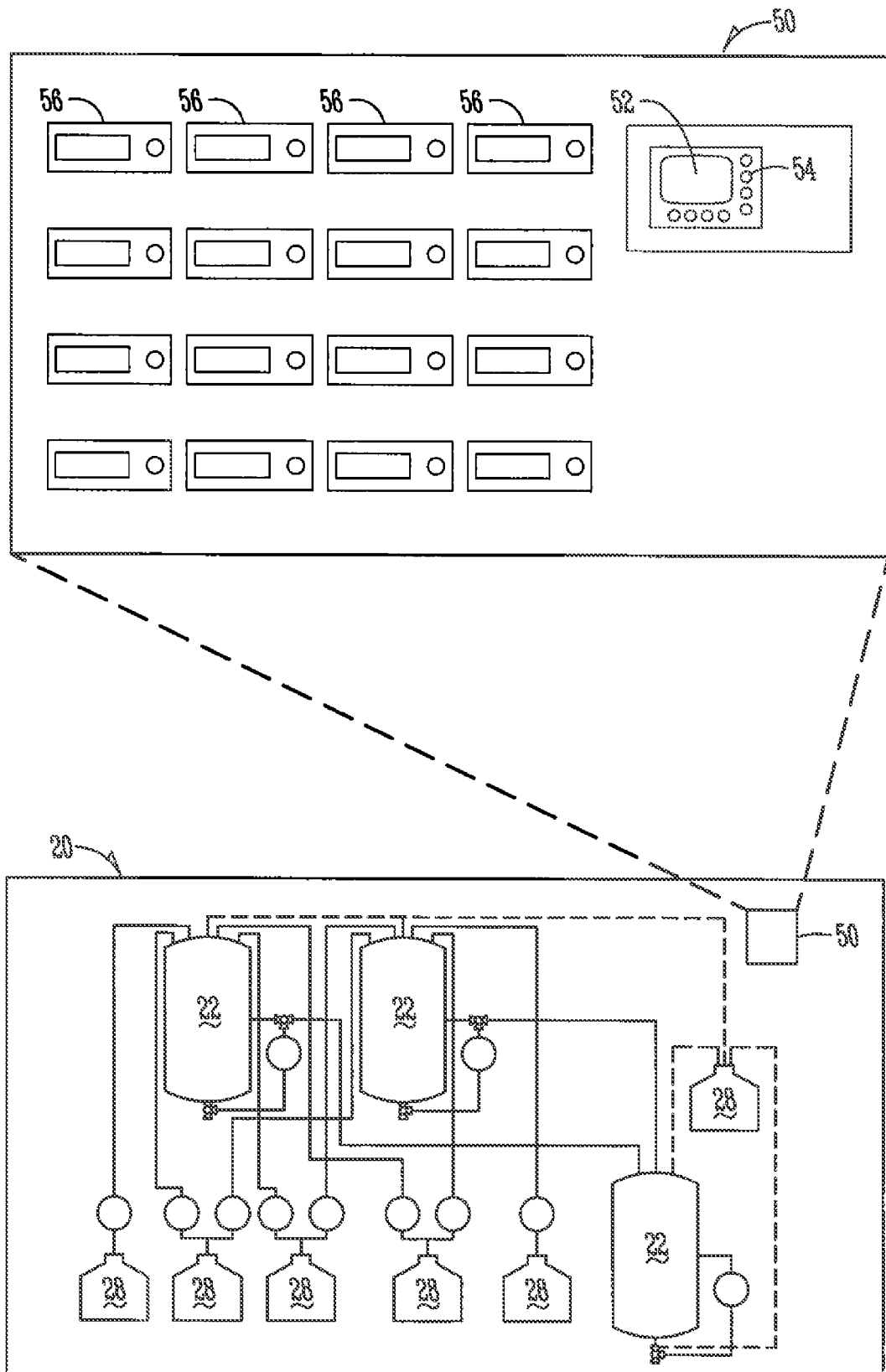


Fig.5

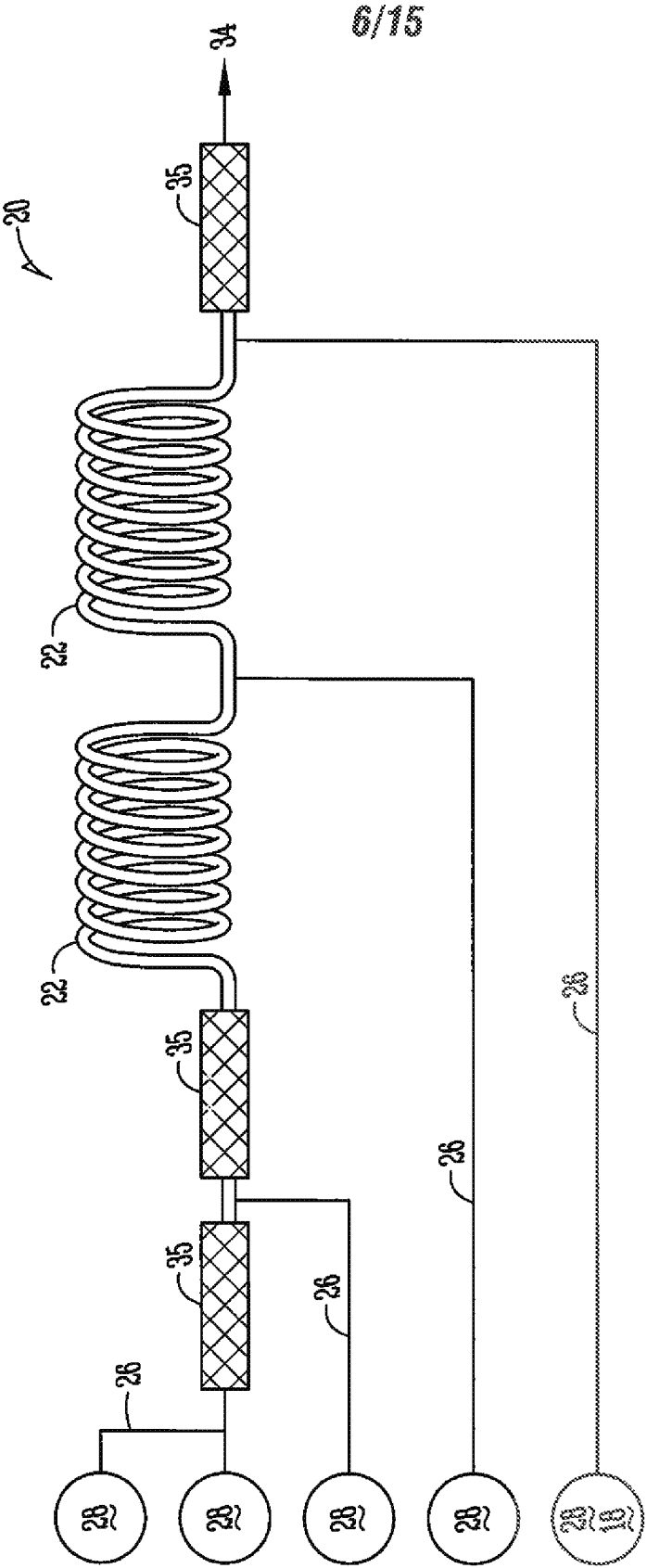


Fig.6

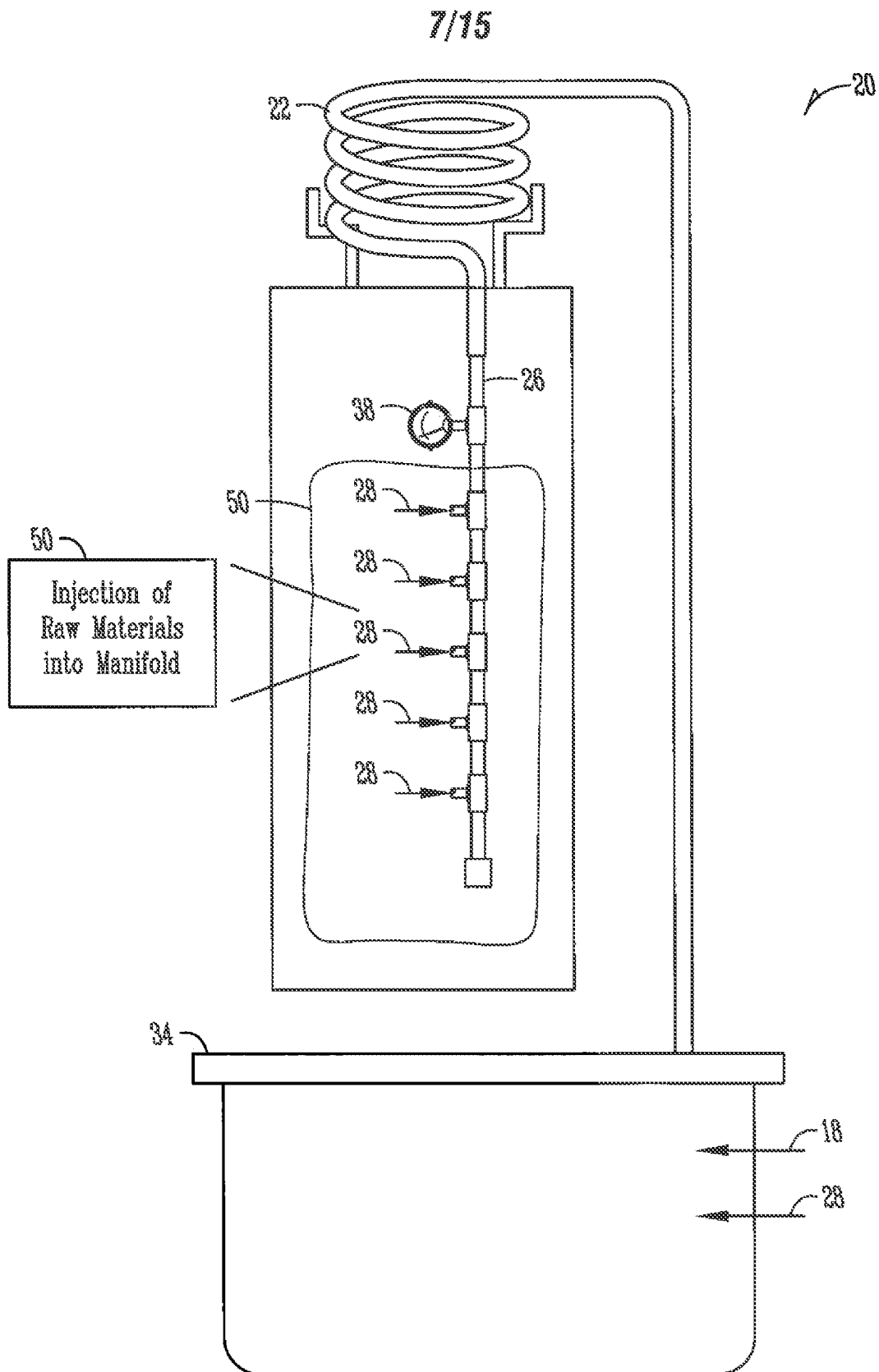


Fig.7

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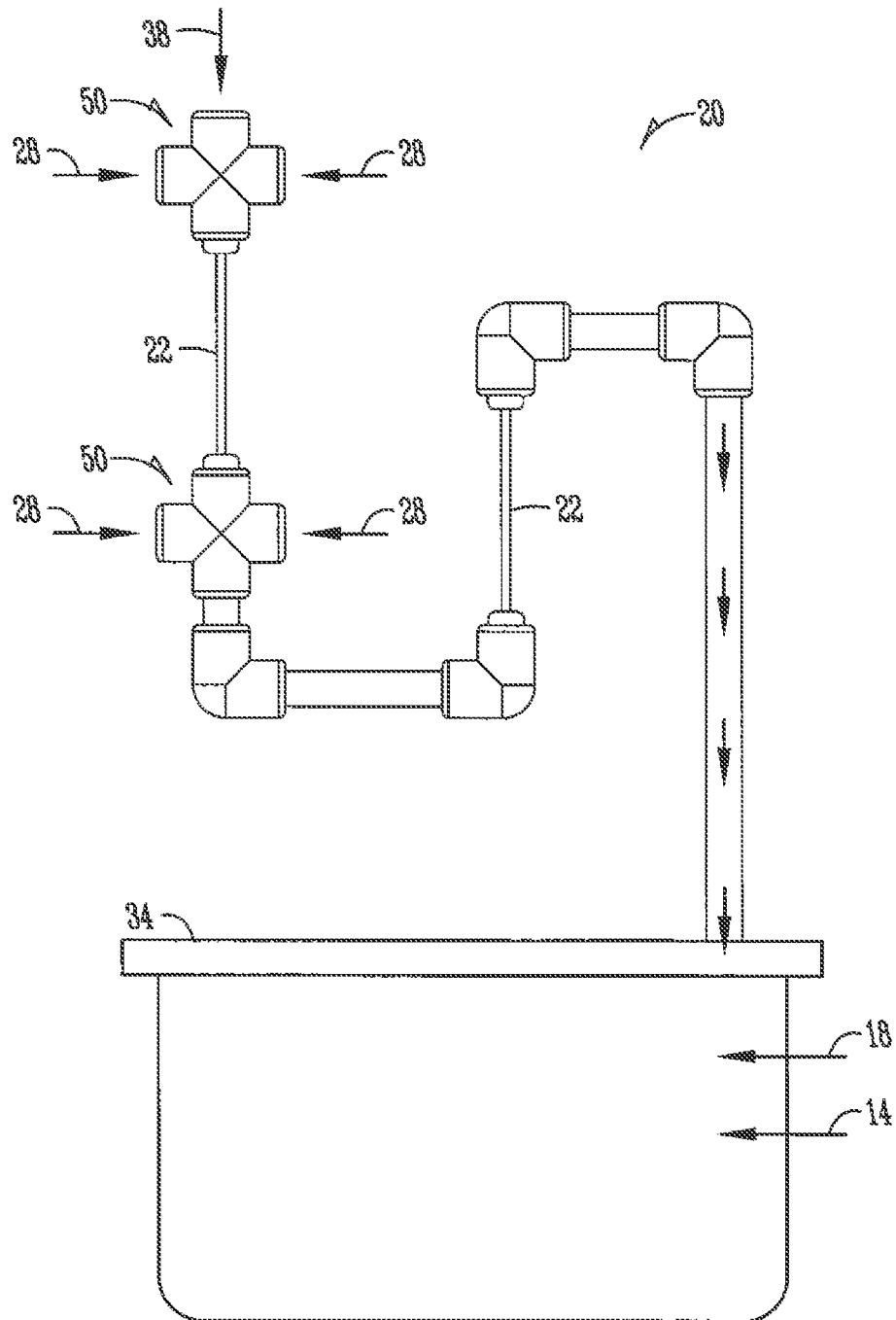


Fig. 8A

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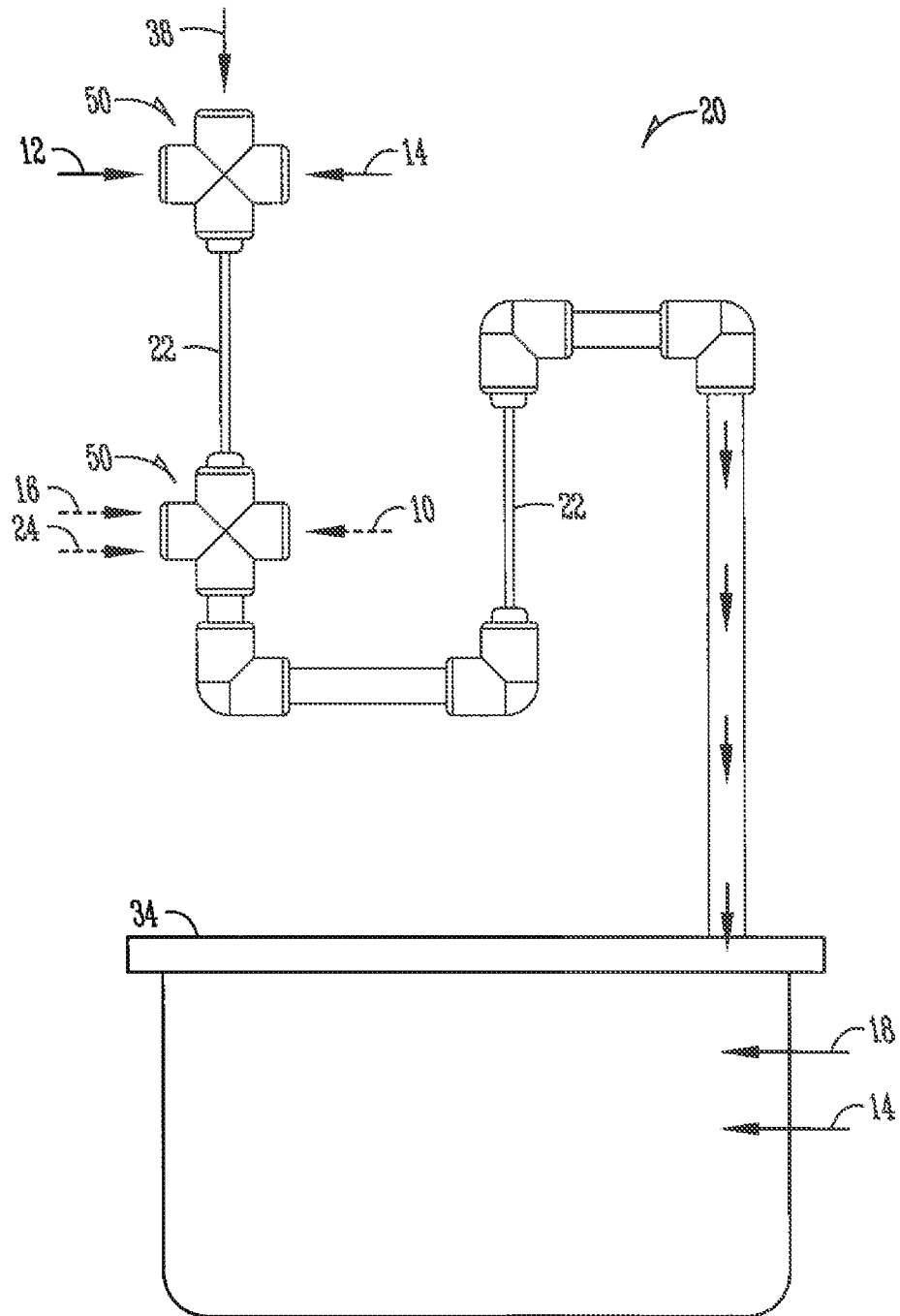


Fig. 8B

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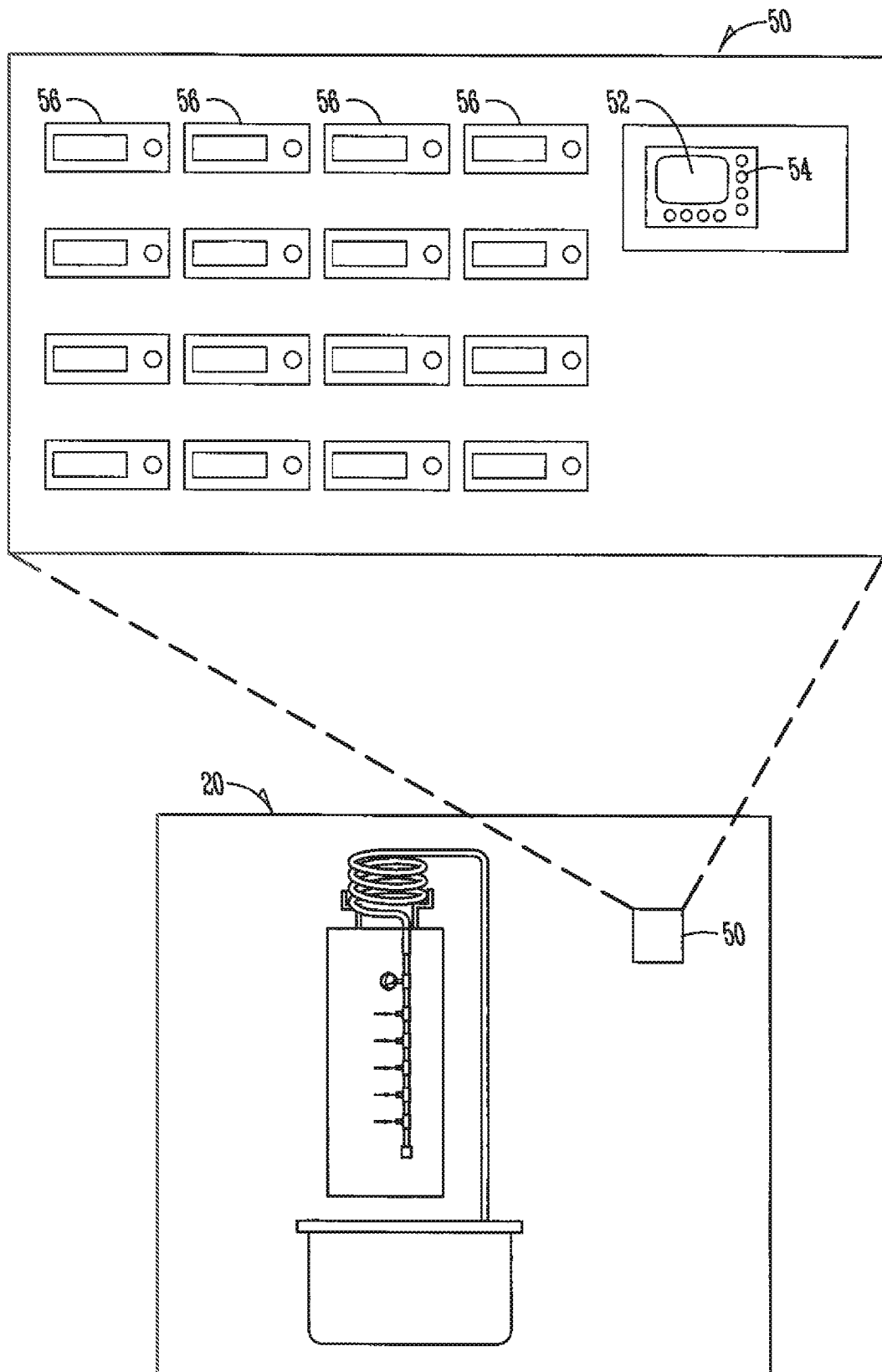
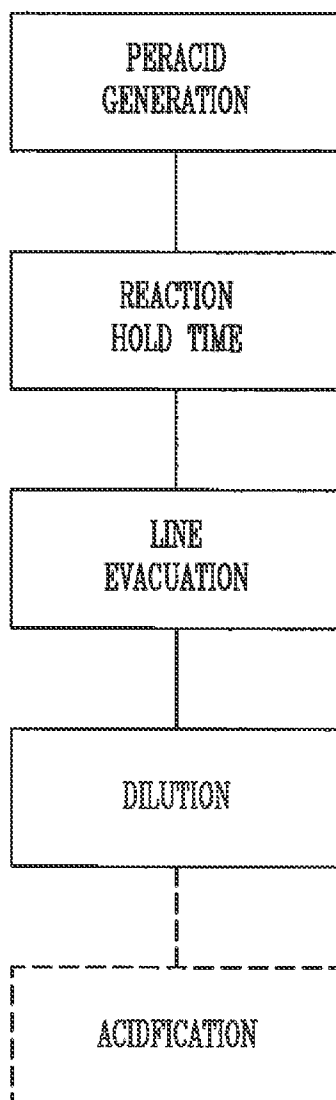


Fig.9

11/15*Fig. 10A*

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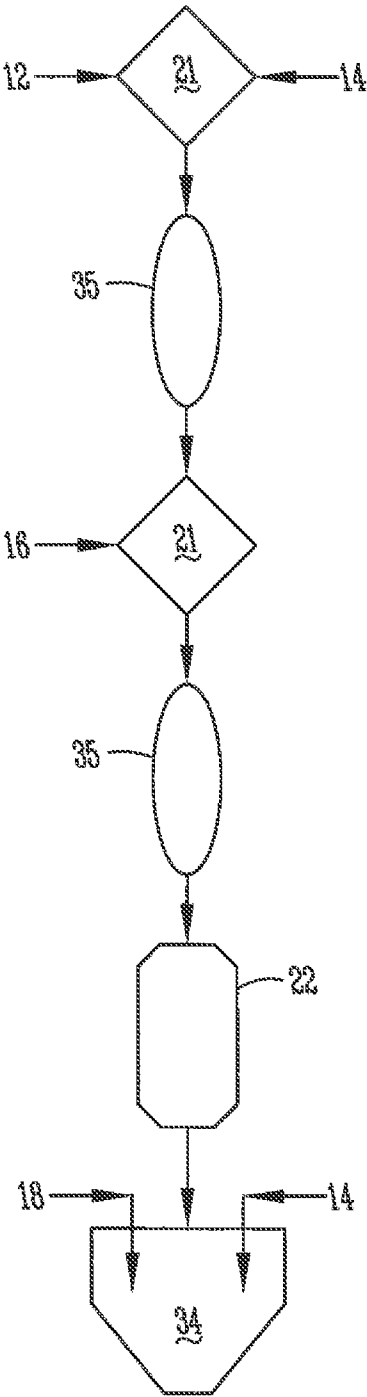


Fig.10B

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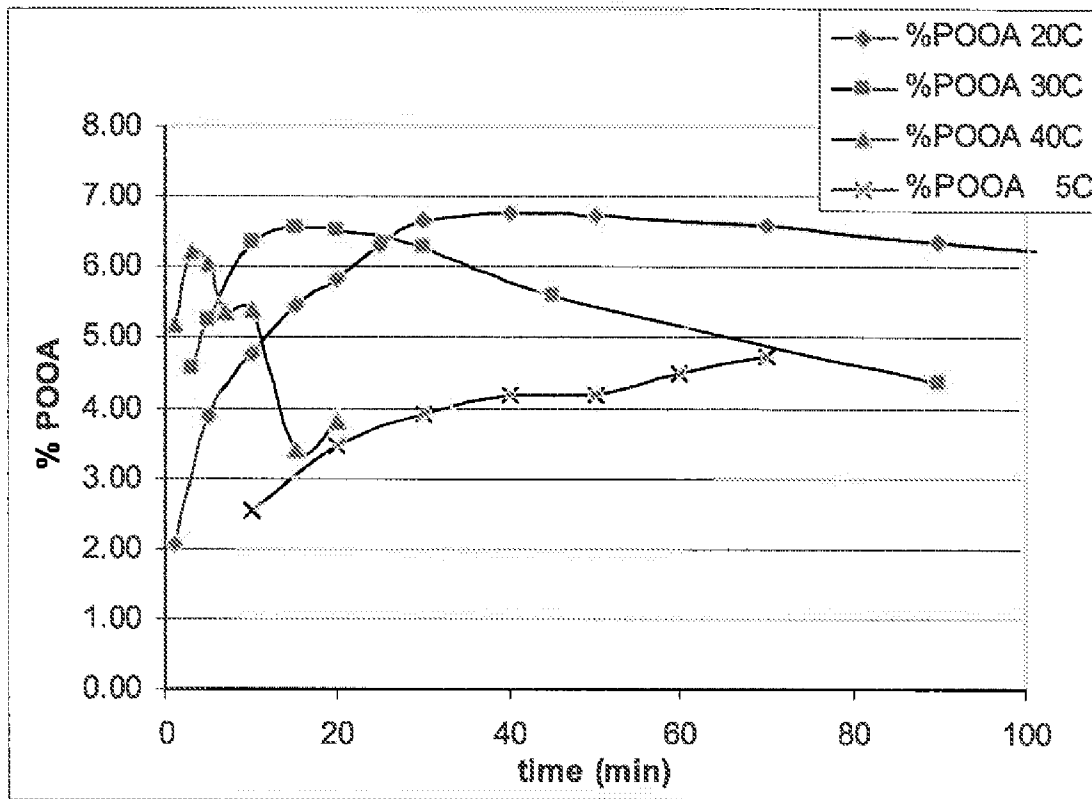


Fig.11

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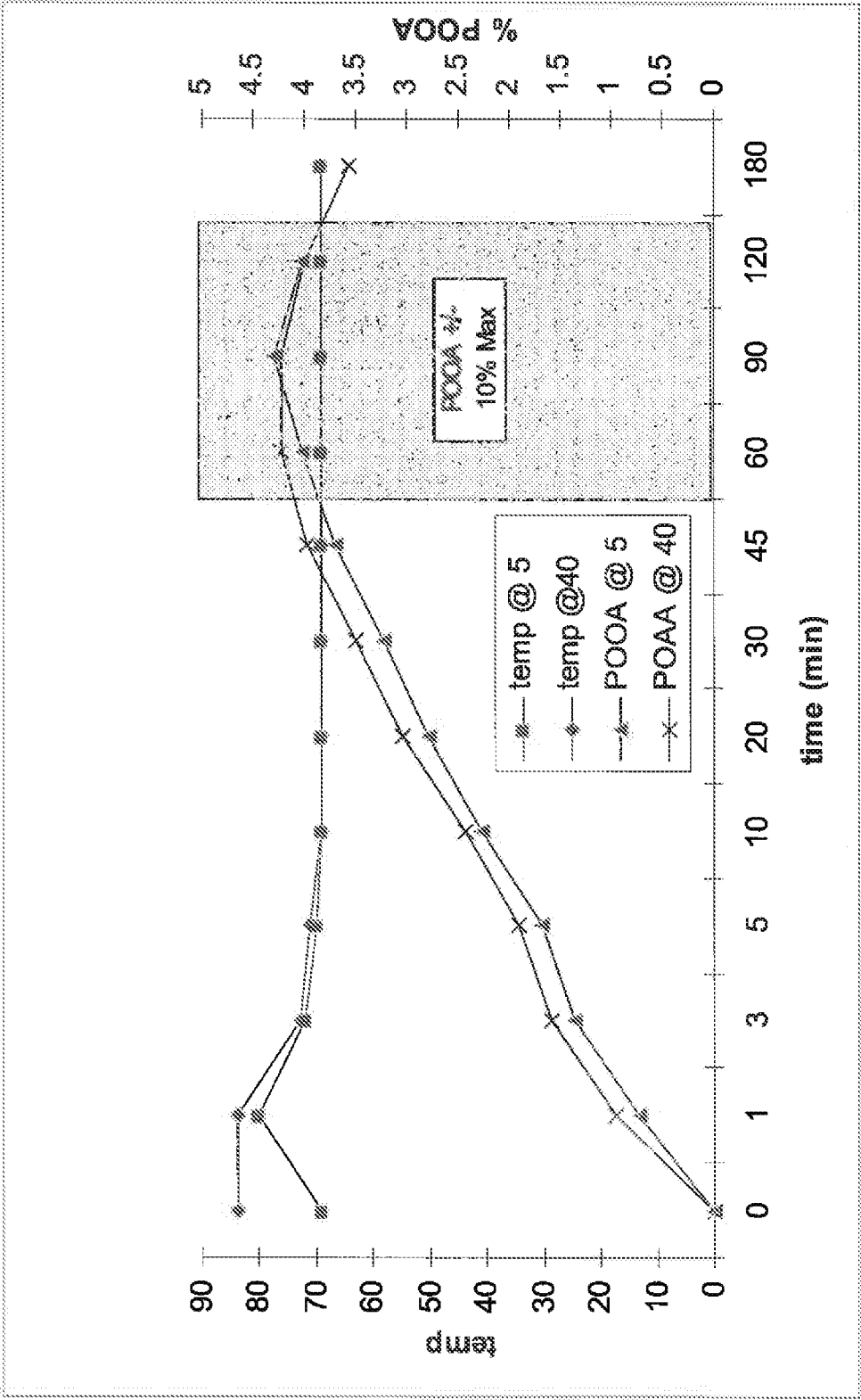


Fig.12

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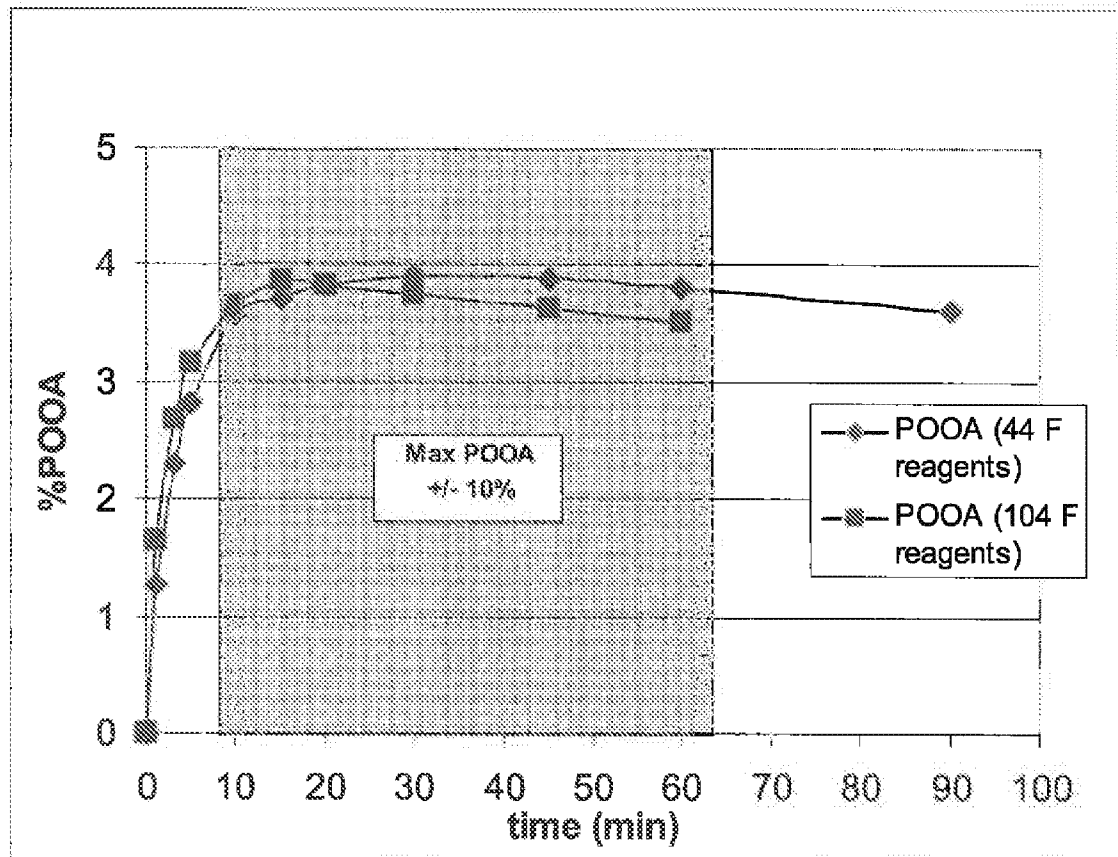


Fig.13