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(54) **APPARATUS AND METHOD FOR  
GENERATING THERMALLY-ENHANCED  
TREATMENT LIQUIDS**

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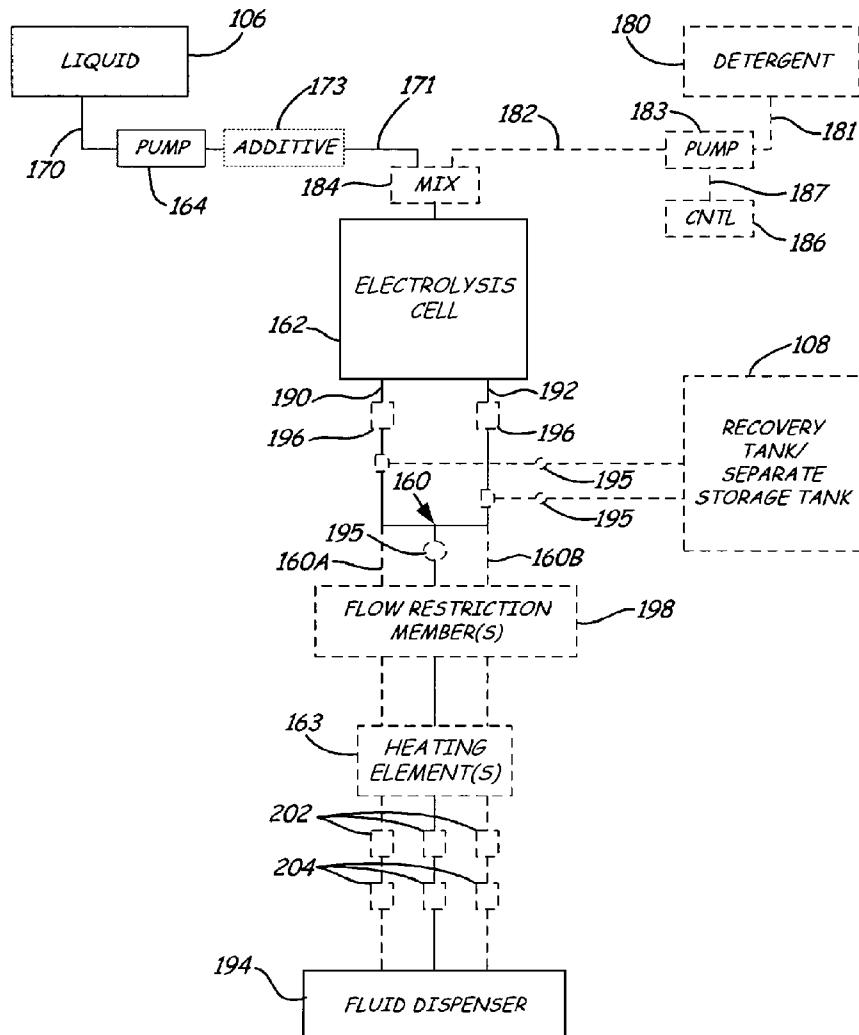
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(57) **ABSTRACT**

A cleaning system comprising a liquid source configured to provide a feed liquid, an electrolysis cell configured to receive the feed liquid and to electrochemically activate the feed liquid to provide an electrochemically-activated liquid, where the electrochemical activation also heats the feed liquid such that the electrochemically-activated liquid is heated, and a dispenser configured to dispense the electrochemically-activated liquid.



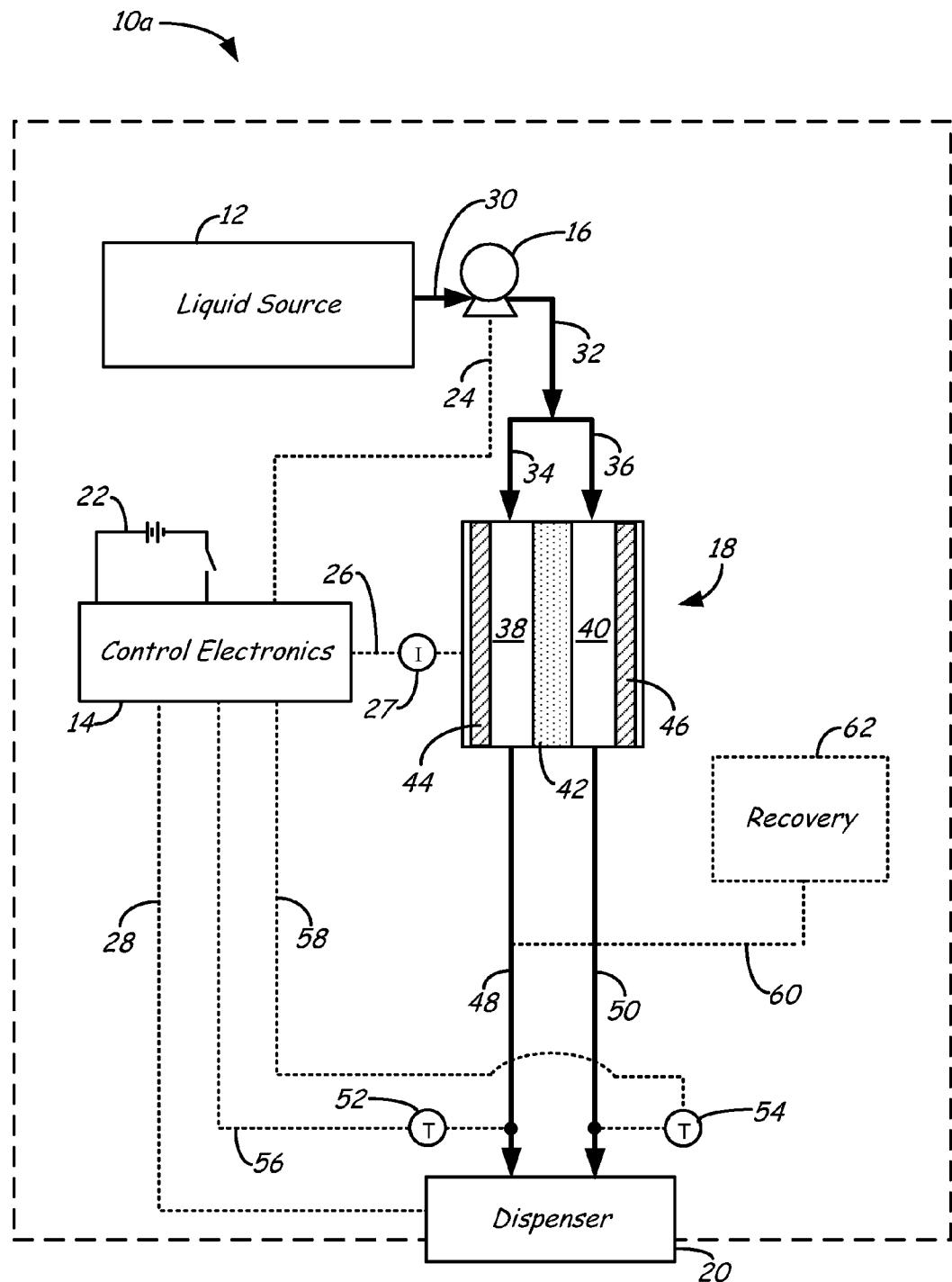
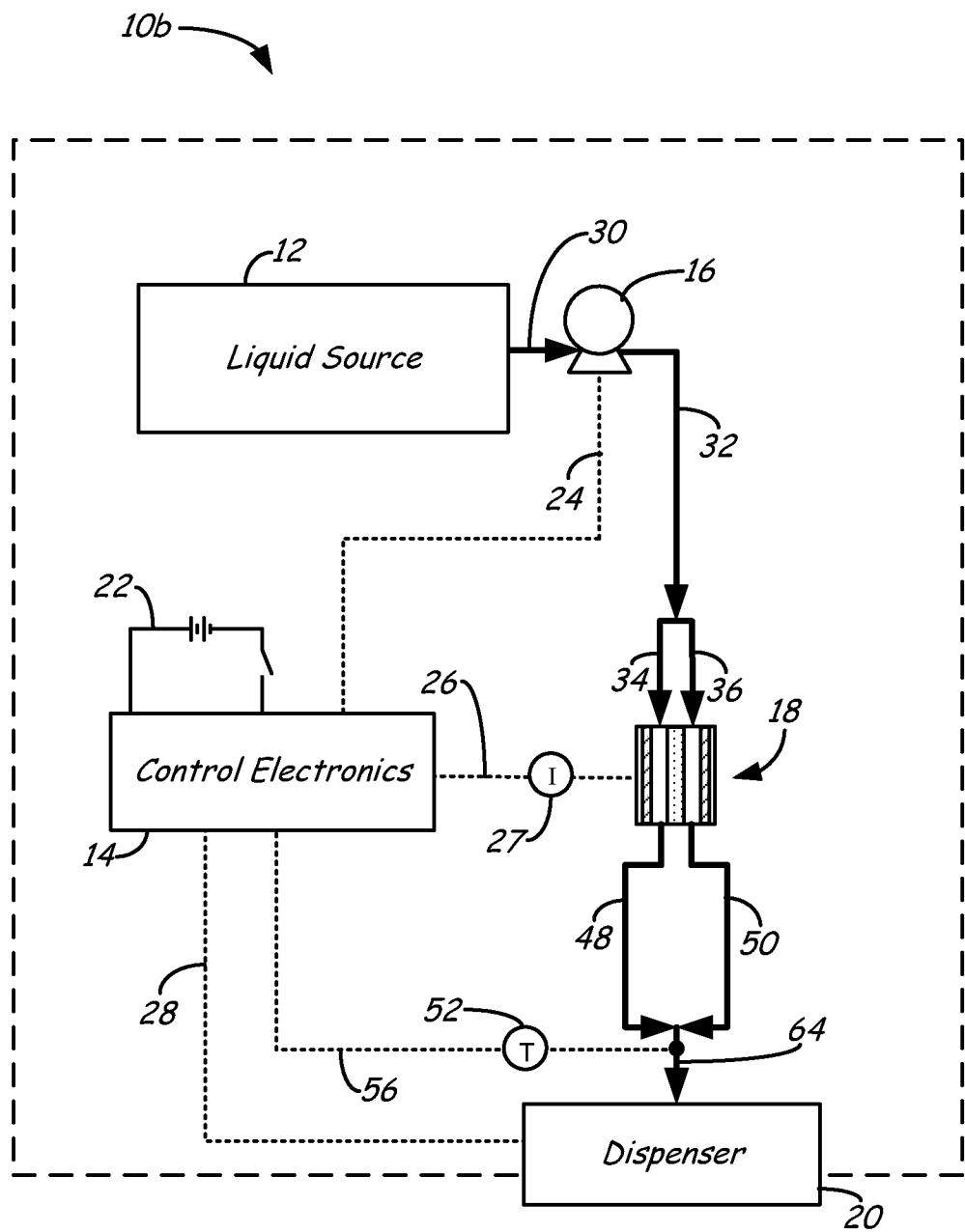


FIG. 1



*FIG. 2*

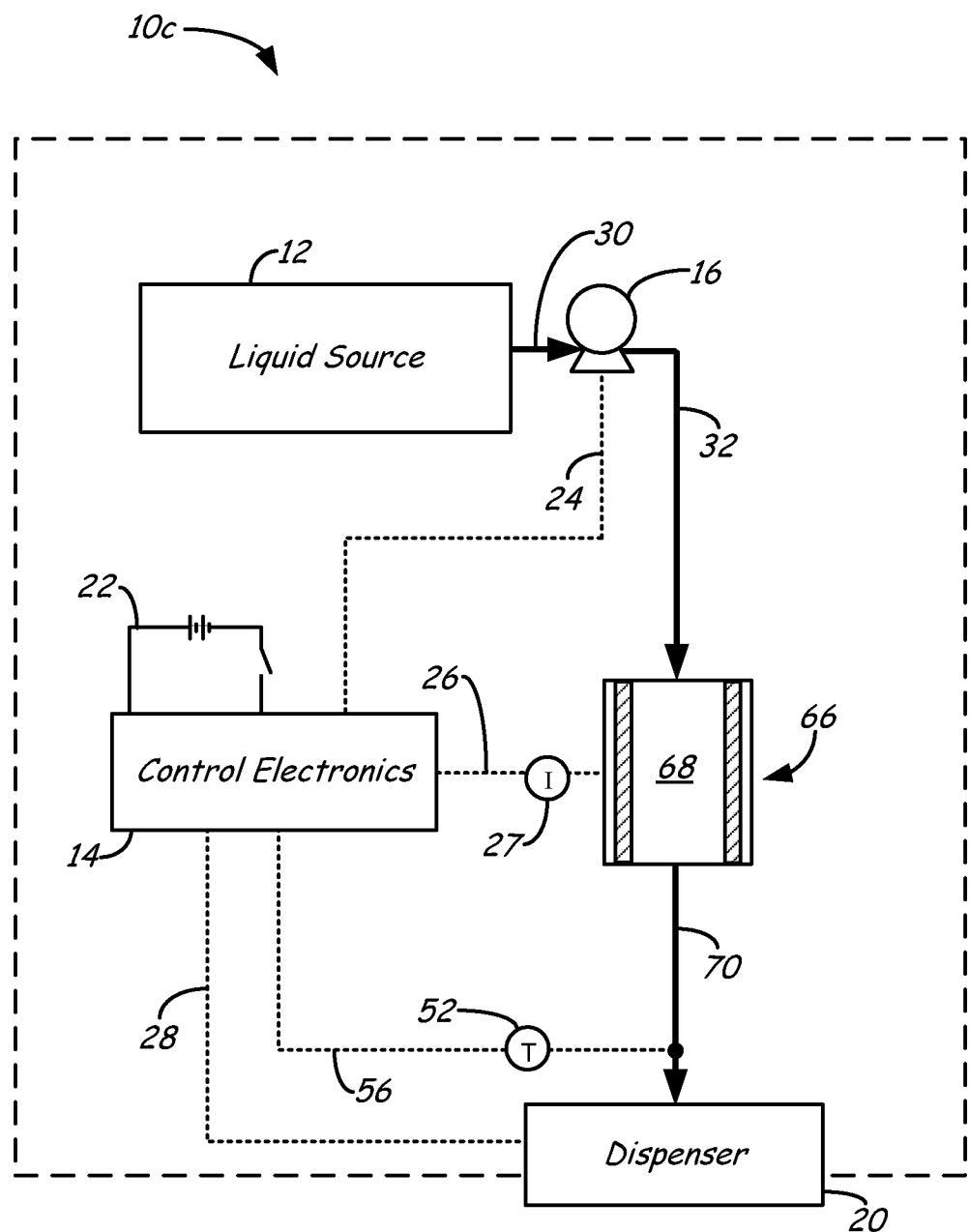


FIG. 3

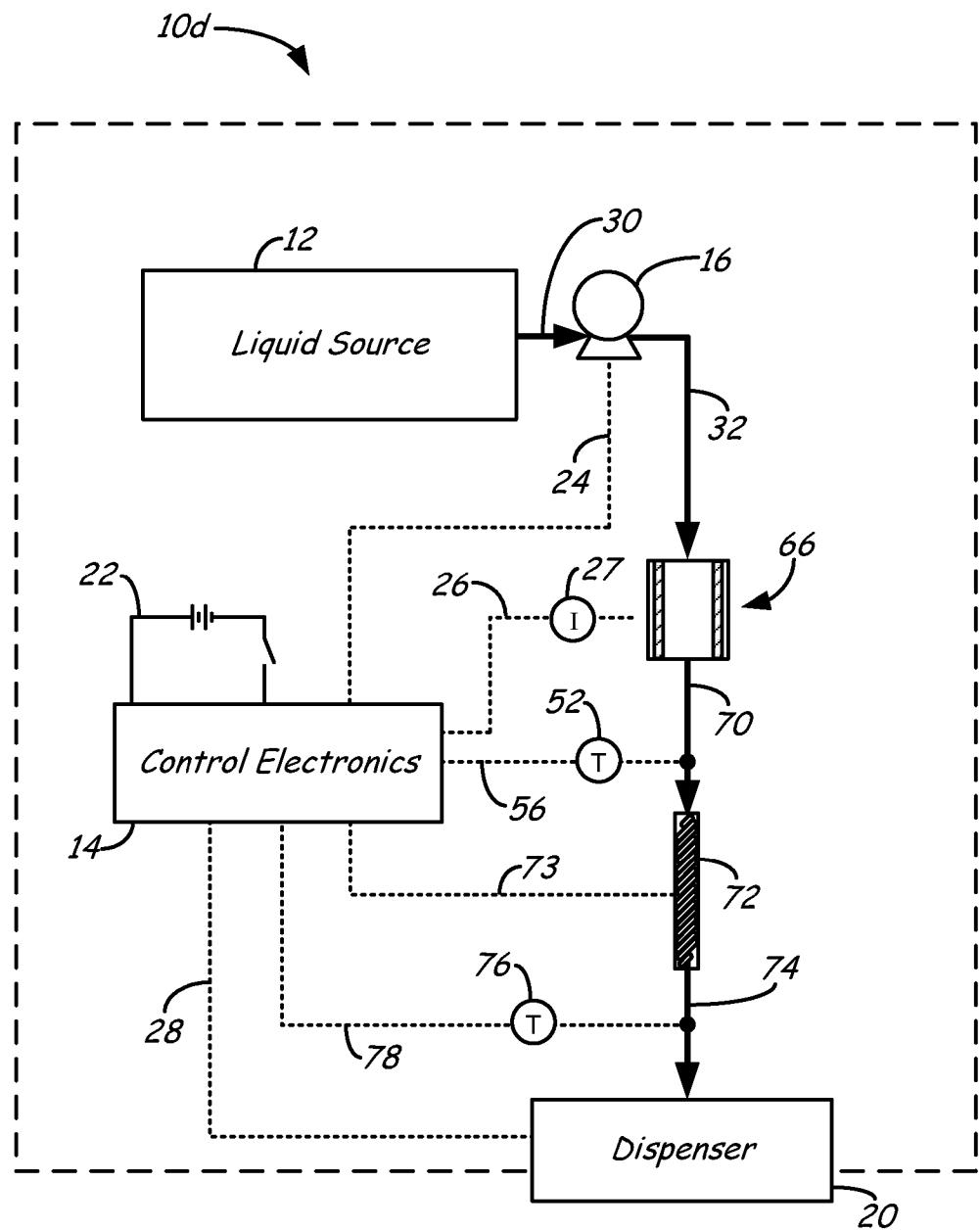


FIG. 4

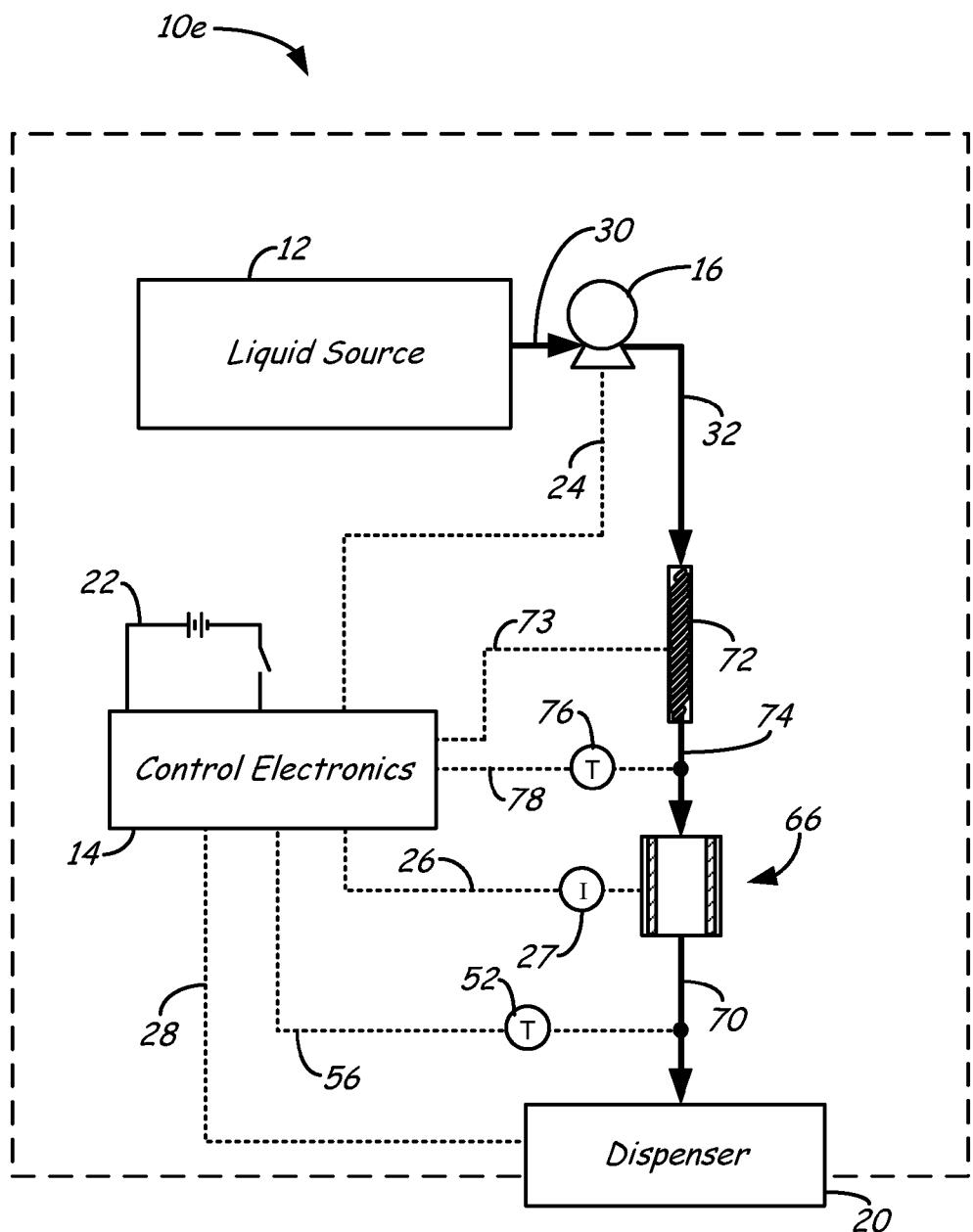
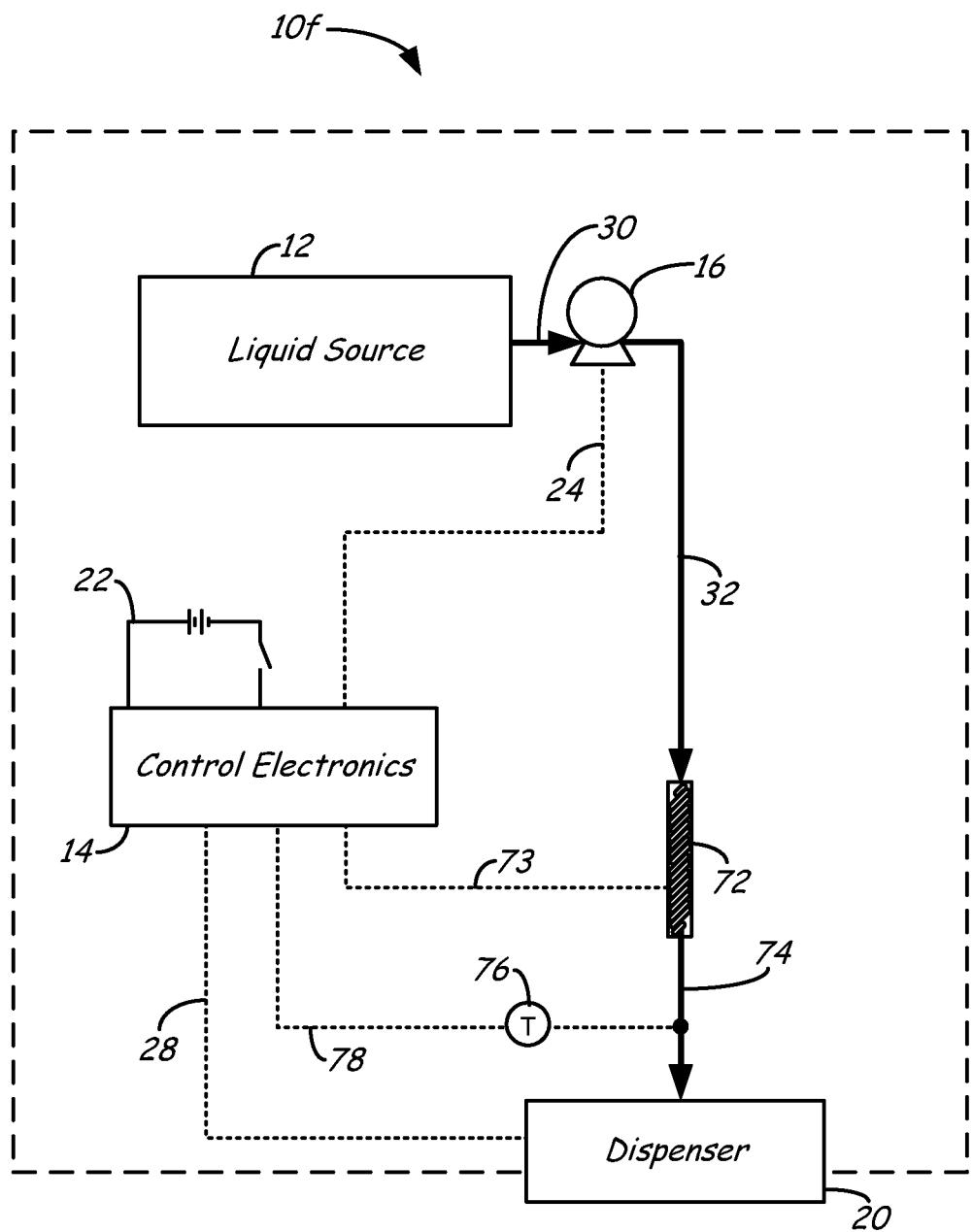
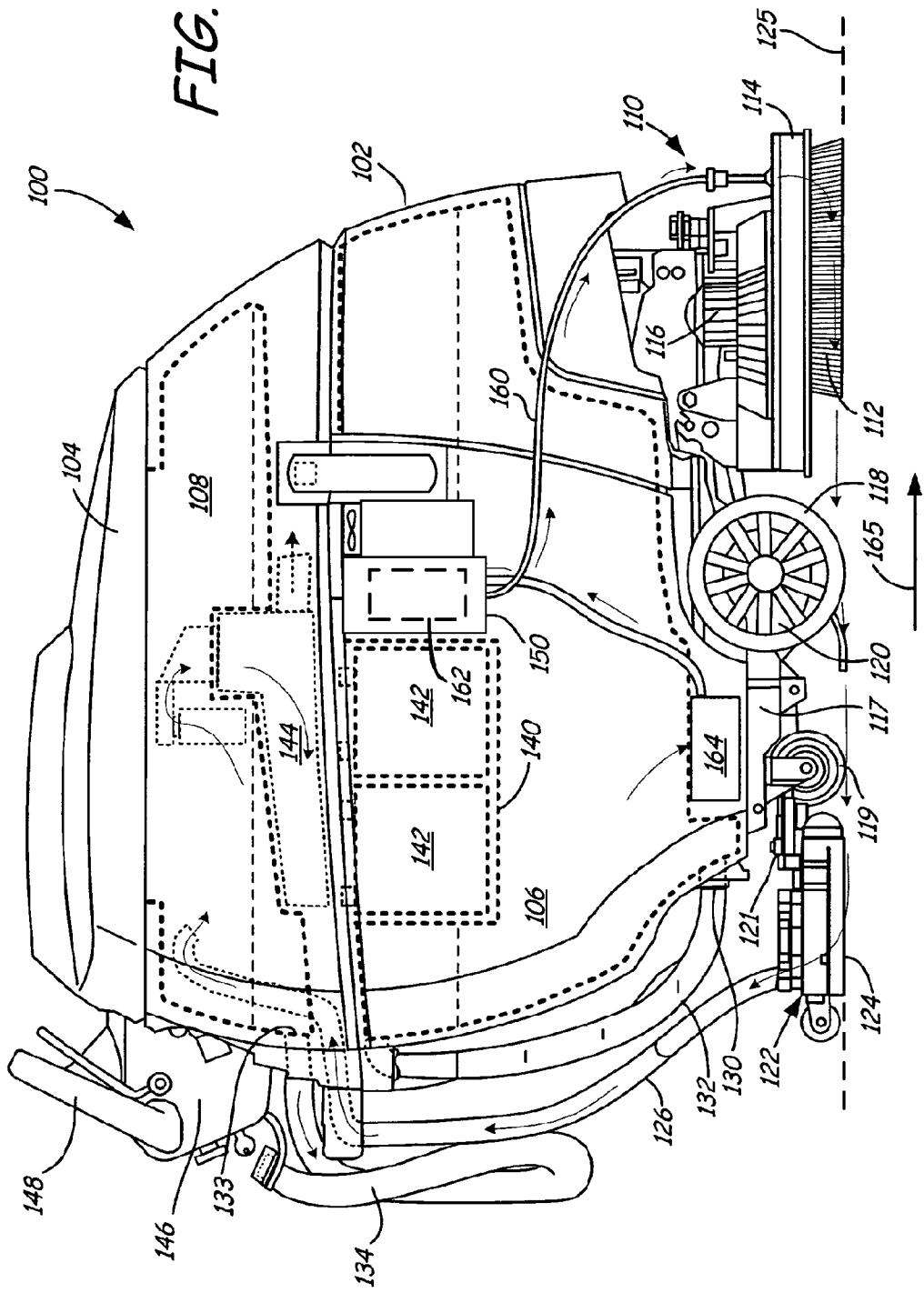


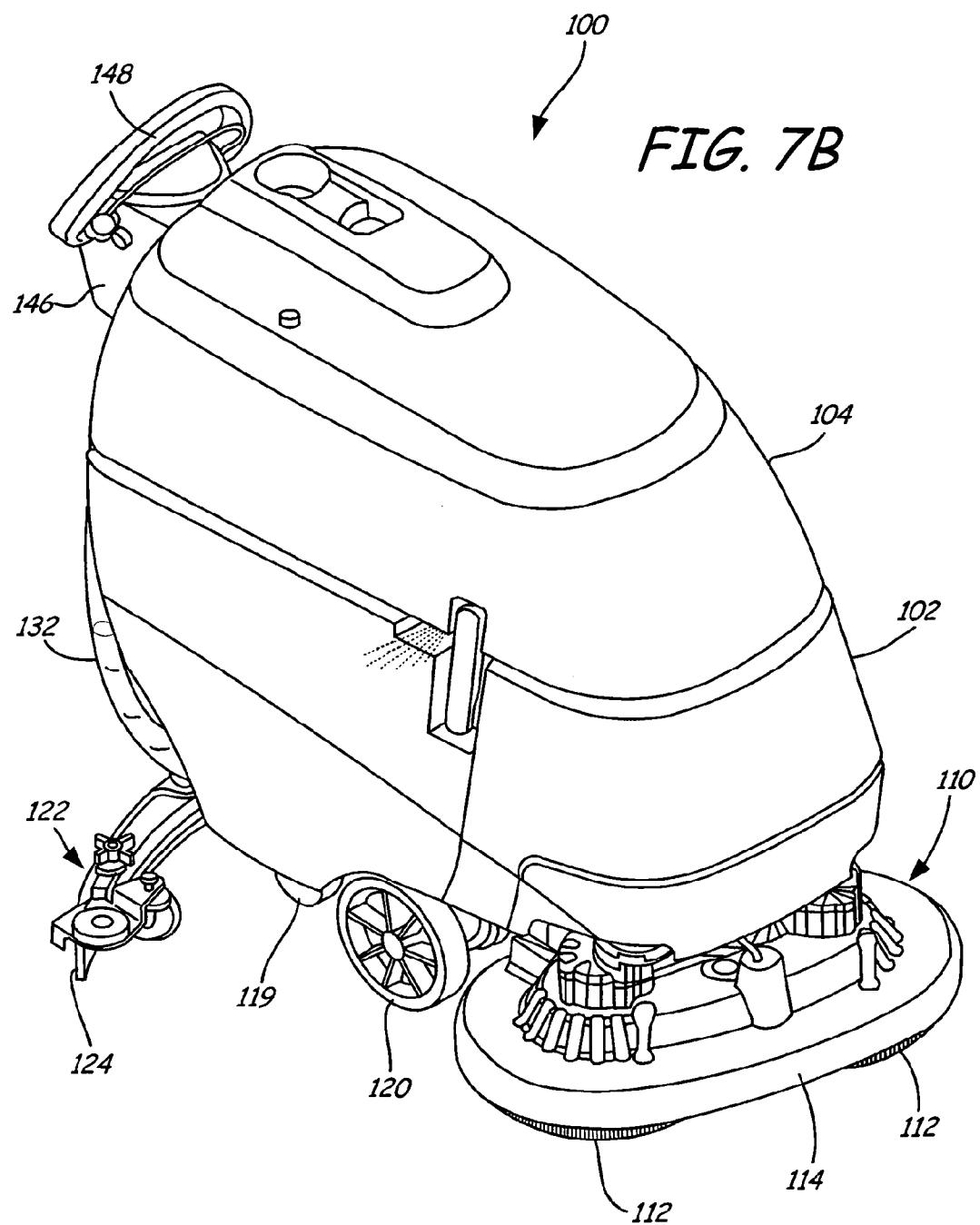
FIG. 5



*FIG. 6*

FIG. 7A





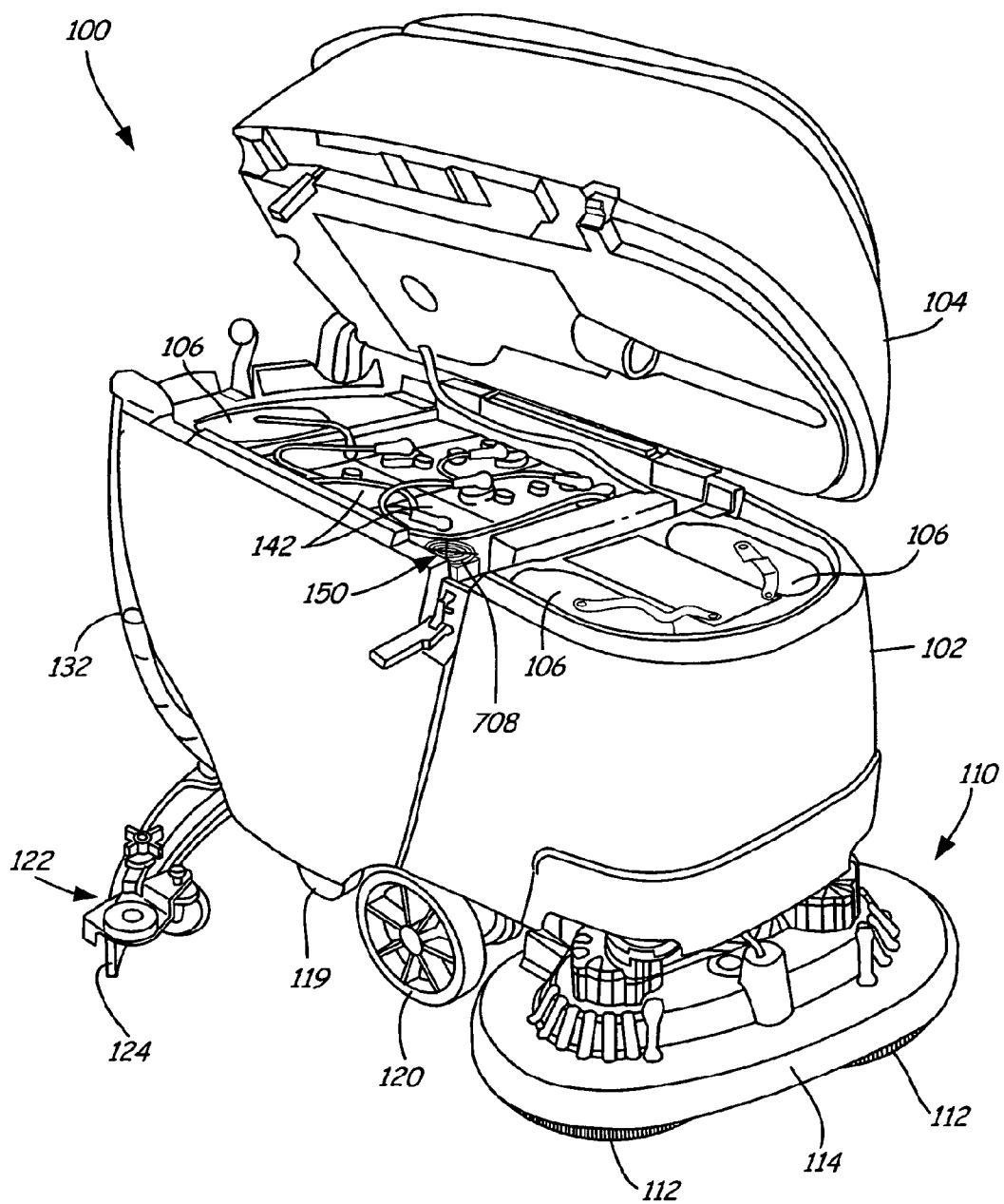


FIG. 7C

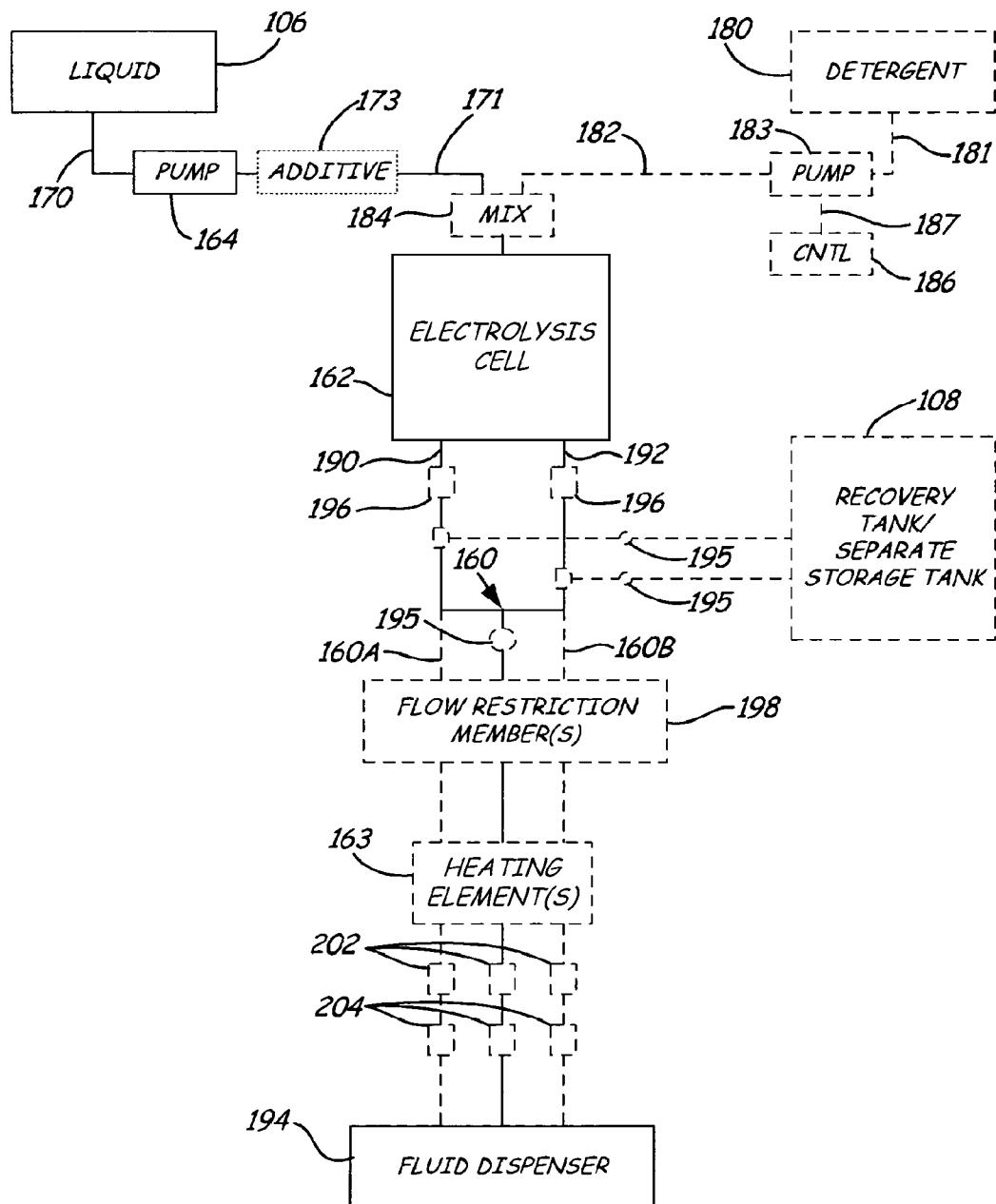


FIG. 8

## APPARATUS AND METHOD FOR GENERATING THERMALLY-ENHANCED TREATMENT LIQUIDS

### CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/590,963, filed on Jan. 26, 2012, and entitled "APPARATUS AND METHOD FOR GENERATING THERMALLY-ENHANCED TREATMENT LIQUIDS", which is incorporated by reference in its entirety.

### FIELD

[0002] The present disclosure relates to cleaning and/or sanitizing systems, and more particularly to systems and methods that generate thermally-enhanced liquids having cleaning and/or sanitizing properties.

### BACKGROUND

[0003] A wide variety of systems are in use today for cleaning or disinfecting residential, industrial, commercial, hospital, food processing, and restaurant facilities, such as surfaces and other substrates, and for cleaning or disinfecting various items, such as food products or other articles.

[0004] For example, hard floor surface scrubbing machines are widely used to clean the floors of industrial and commercial buildings. They range in size from a small model, which is controlled by an operator walking behind it, to a large model, which is controlled by an operator riding on the machine. Such machines in general are wheeled vehicles with suitable operator controls. Their bodies contain power and drive elements, a solution tank to hold a cleaning liquid, and a recovery tank to hold soiled solution recovered from the floor being scrubbed. A scrub head, which contains one or more scrubbing brushes and associated drive elements are attached to the vehicle and may be located in front of, under or behind it. A solution distribution system dispenses cleaning liquid from the solution tank to the floor in the vicinity of the scrubbing brush or brushes.

[0005] Soft floor cleaning machines can be implemented as small mobile machines that are handled by an operator or can be implemented in a truck-mounted system having a cleaning wand connected to the truck. The truck carries a cleaning liquid solution tank, a wastewater recovery tank and a powerful vacuum extractor.

[0006] Typical cleaning liquids used in hard and soft floor cleaning systems include water and a chemically based detergent. The detergent typically includes a solvent, a builder, and a surfactant. While these detergents increase cleaning effectiveness for a variety of different soil types, such as dirt and oils, these detergents also have a tendency to leave unwanted residue on the cleaned surface. Such residue can adversely affect the appearance of the surface and the tendency of the surface to re-soil and, depending on the detergent, can potentially cause adverse health or environment effects. Similar disadvantages apply to cleaning systems for other types of surfaces and items. Improved cleaning systems are desired for reducing the use of typical detergents and/or reducing the residue left on the surface after cleaning while maintaining desired cleaning and/or disinfecting properties, for example.

### SUMMARY

[0007] An aspect of the present disclosure is directed to a cleaning system. The cleaning system includes a liquid source configured to provide a feed liquid at a first temperature, and an electrolysis cell configured to receive the feed liquid and to electrochemically activate the feed liquid to provide an electrochemically-activated liquid. The electrochemical activation also heats the feed liquid such that the electrochemically-activated liquid is at a second temperature that is greater than the first temperature. The cleaning system also includes a dispenser configured to dispense the electrochemically-activated liquid. In some embodiments, the cleaning system may include one or more heating elements upstream and/or downstream of the electrolysis cell.

[0008] Another aspect of the present disclosure is directed to a cleaning system that includes a liquid source configured to provide a feed liquid at a first temperature, and a heating element configured to heat the feed liquid to a second temperature that is greater than the first temperature. The cleaning system also includes a dispenser configured to dispense the heated liquid. In some embodiments, the cleaning system may also include an electrolysis cell.

[0009] Another aspect of the present disclosure is directed to a method for cleaning a surface. The method includes pumping a feed liquid having a first temperature from a liquid source to an electrolysis cell, electrochemically activating and heating the feed liquid in the electrolysis cell to provide an electrochemically-activated liquid at an elevated temperature that is greater than the first temperature, and dispensing the electrochemically-activated liquid to the surface.

[0010] Another aspect of the present disclosure is directed to a method for cleaning a surface, which includes pumping a feed liquid from a liquid source to an electrolysis cell, and inducing a current through the electrolysis cell to electrochemically activate and heat the feed liquid in the electrolysis cell to provide an electrochemically-activated liquid. The method also includes directing at least a portion of the electrochemically-activated liquid through a fluid line, monitoring a temperature of the electrochemically-activated liquid in the fluid line, controlling at least one of the pumping and the inducing of the current in response to the monitored temperature, and dispensing the at least one portion of the electrochemically-activated liquid to the surface.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a schematic illustration of a cleaning system of the present disclosure, which includes an electrolysis cell for electrochemically activating and heating a feed liquid.

[0012] FIG. 2 is a schematic illustration of a first alternative cleaning system of the present disclosure, which includes an electrolysis cell having combined outlet streams.

[0013] FIG. 3 is a schematic illustration of a second alternative cleaning system of the present disclosure, which includes an electrolysis cell without a cell barrier.

[0014] FIG. 4 is a schematic illustration of a third alternative cleaning system of the present disclosure, which includes an electrolysis cell and a heating element located downstream from the electrolysis cell.

[0015] FIG. 5 is a schematic illustration of a fourth alternative cleaning system of the present disclosure, which includes an electrolysis cell and a heating element located upstream from the electrolysis cell.

[0016] FIG. 6 is a schematic illustration of a fifth alternative cleaning system of the present disclosure, which includes a heating element for heating a feed liquid.

[0017] FIG. 7A is a side elevation view of a mobile hard floor surface cleaner in accordance with one or more exemplary embodiments of the disclosure.

[0018] FIG. 7B is a perspective view of the mobile hard floor surface cleaner shown in FIG. 7A with its lid in a closed state.

[0019] FIG. 7C is a perspective view of the mobile hard floor surface cleaner shown in FIG. 7A with its lid in an open state.

[0020] FIG. 8 is a block diagram illustrating a liquid distribution flow path of the cleaner shown in FIGS. 7A-7C in greater detail according to an embodiment of the disclosure.

#### DETAILED DESCRIPTION

[0021] The present disclosure is directed to a system and method for generating a thermally-enhanced treatment liquid for cleaning surfaces. As discussed below, the system may incorporate an electrolysis cell that electrochemically activates a feed liquid (e.g., water) to generate an alkaline or basic catholyte liquid, an acidic anolyte liquid, or a blended combination of the alkaline and acidic species. In one embodiment, the electrolysis cell is configured to heat the feed liquid during electrolysis to increase the cleaning properties of the liquid, where the electrolysis cell may be controlled to maintain a desired temperature and electrochemical properties for the output electrochemically-activated liquid.

[0022] In some embodiments, the system may also include one or more heating elements to heat the liquid. For example, the heating element(s) may heat the liquid in coordination with an electrolysis cell to attain a desired temperature for the output electrochemically-activated liquid.

[0023] FIG. 1 is a simplified, schematic diagram of cleaning system 10a, which is an example of a suitable cleaning system of the present disclosure to generate thermally-enhanced treatment liquids for cleaning surfaces. As shown, system 10a includes liquid source 12, control electronics 14, pump 16, electrolysis cell 18, and dispenser 20.

[0024] Liquid source 12 is a reservoir or fluid line coupling for containing and/or receiving a feed liquid to be treated and then dispensed by cleaning system 10a. In some embodiments, the feed liquid may include one or more additives, such as electrolytic compositions (e.g. salts), which are desirably dissolved or otherwise suspended in the feed liquid. In other embodiments, the feed liquid may consist essentially of tap water. The following discussion of the cleaning systems of the present disclosure (e.g., cleaning system 10a) is made with reference to water (e.g., tap water) as the feed liquid with the understanding that the cleaning systems of the present disclosure may be used with a variety of different feed liquids.

[0025] Control electronics 14 includes a printed circuit board containing electronic devices for powering and controlling the operation of pump 16, electrolysis cell 18, dispenser 20, and optionally, other suitable components of cleaning system 10a (e.g., an electric motor). For example, control electronics 14 may apply electrical power from electrical source 22 to pump 16, electrolysis cell 18, and dispenser 20, respectively over electrical lines 24, 26, and 28 during operation.

[0026] In one embodiment, control electronics 14 simultaneously applies electrical power to pump 16, electrolysis cell 18, and dispenser 20. This embodiment is beneficial for pro-

viding an on-demand activation of pump 16, electrolysis cell 18, and dispenser 20, such as when a user of cleaning system 10a actuates a lever or other control mechanism (not shown). Alternatively, control electronics 14 may independently apply electrical power to pump 16, electrolysis cell 18, and/or dispenser 20. In some embodiments, dispenser 20 may be a passive dispenser that is not directly operated by control electronics 14, for example.

[0027] Pump 16 is a liquid pump operated by control electronics 14 to draw the feed water from liquid source 12 through fluid line 30 at a predetermined flow rate. The predetermined flow rate may be based on a fixed pumping rate, or may be adjustable by control electronics 12 over electrical line 24, thereby allowing the flow rate of the feed water to be adjusted.

[0028] In the shown embodiment, pump 16 is located downstream from liquid source 12 and upstream from electrolysis cell 18 for drawing water from liquid source 12 to electrolysis cell 18. In alternative embodiments, pump 16 may be positioned at any suitable location between liquid source 12 and dispenser 20.

[0029] Electrolysis cell 18 receives the pumped feed water from pump 16 over fluid line 32, which splits into inlet lines 34 and 36 prior to (or after) entering electrolysis cell 18. In particular, a first portion of the feed water may flow through inlet line 34, and is directed into anode chamber 38 of electrolysis cell 18. Correspondingly, a second portion of the feed water in inlet line 36 is directed into anode chamber 40 of electrolysis cell 18. While illustrated as a single cell, cleaning system 10a may alternatively include multiple electrolysis cells 18 arranged serially and/or in parallel.

[0030] Electrolysis cell 18 also includes barrier 42, anode electrode 44, and cathode electrode 46, where barrier 42 includes a membrane or other diaphragm that separates anode chamber 38 and cathode chamber 40. Anode electrode 44 includes one or more electrodes located in anode chamber 38. Correspondingly, cathode electrode 46 includes one or more electrodes located in cathode chamber 40.

[0031] In embodiments in which barrier 42 is a membrane, barrier 42 can include a cation exchange membrane (i.e., a proton exchange membrane) or an anion exchange membrane. Suitable cation exchange membranes for barrier 42 include partially and fully fluorinated ionomers, polyaromatic ionomers, and combinations thereof. Examples of suitable commercially available ionomers for barrier 42 include sulfonated tetrafluoroethylene copolymers available under the trademark "NAFION" from E.I. du Pont de Nemours and Company, Wilmington, Del.; perfluorinated carboxylic acid ionomers available under the trademark "FLEMION" from Asahi Glass Co., Ltd., Japan; perfluorinated sulfonic acid ionomers available under the trademark "ACIPLEX" Aciplex from Asahi Chemical Industries Co. Ltd., Japan; and combinations thereof.

[0032] Electrodes 44 and 46 can be made from any suitable material, such as titanium and/or titanium coated with a precious metal, such as platinum, or any other suitable electrode material. The electrodes and respective chambers can have any suitable shape and construction. For example, electrodes 44 and 46 can be flat plates, coaxial plates, rods, or a combination thereof, and may be solid or mesh (i.e., porous).

[0033] Electrodes 44 and 46 are electrically connected to opposite terminals of a power supply, such as electrical source 22, through control electronics 14 and electrical line 26. During operation, control electronics 14 may apply a voltage

potential across anode electrode **44** and cathode electrode **46**. Control electronics **14** can provide a constant DC output voltage, a pulsed or otherwise modulated DC output voltage, and/or a pulsed or otherwise modulated AC output voltage to electrodes **44** and **46**, for example. In the shown embodiment, cleaning system **10a** may also include current sensor **27** located along electrical line **26** and/or within electrolysis cell **18** to detect the intensity of the current induced through electrolysis cell **18**.

[0034] The applied voltage induces an electrical current across electrolysis cell **18** to generate an anolyte stream containing acidic water from the feed water flowing through anode chamber **38**. This reaction also generates a catholyte stream containing an alkaline water from the feed water flowing through cathode chamber **40**. The resulting anolyte stream exits anode chamber **38** through output line **48**, and the catholyte stream exits cathode chamber **40** through output line **50**.

[0035] In the case of a cation exchange membrane for barrier **42**, upon application of a voltage potential across electrodes **44** and **46**, cations originally present in the anode chamber **38** move across barrier **42** towards cathode electrode **46** while anions in anode chamber **38** move towards anode electrode **44**. However, anions present in cathode chamber **40** are not able to pass through barrier **42**, and therefore remain confined within cathode chamber **40**.

[0036] While the electrolysis continues, the anions in the water bind to the metal atoms (e.g., platinum atoms) at anode electrode **44**, and the cations in the water bind to the metal atoms (e.g., platinum atoms) at cathode electrode **46**. These bound atoms diffuse around in two dimensions on the surfaces of the respective electrodes until they take part in further reactions. Other atoms and polyatomic groups may also bind similarly to the surfaces of electrodes **44** and **46**, and may also subsequently undergo reactions. Molecules such as oxygen ( $O_2$ ) and hydrogen ( $H_2$ ) produced at the surfaces may enter small cavities in the liquid phase of the liquid (i.e., bubbles) as gases and/or may become solvated by the liquid phase of the water.

[0037] Surface tension at a gas-liquid interface is produced by the attraction between the molecules being directed away from the surfaces of electrodes **44** and **46** as the surface molecules are more attracted to the molecules within the liquid than they are to molecules of the gas at the electrode surfaces. In contrast, molecules of the bulk of the liquid are equally attracted in all directions. Thus, in order to increase the possible interaction energy, surface tension causes the molecules at the electrode surfaces to enter the bulk of the water. As a result of the electrolysis process, electrolysis cell **18** electrochemically activates the feed water by at least partially utilizing electrolysis and produces electrochemically-activated water in the form of the acidic anolyte stream (through anode chamber **38**) and the basic catholyte stream (through cathode chamber **40**).

[0038] If desired, the anolyte and catholyte streams can be generated in different ratios to one another through modifications to the structure of electrolysis cell **18**. For example, electrolysis cell **18** can be configured to produce a greater volume of the catholyte stream compared to the anolyte stream if the primary function of the electrochemically-activated water is cleaning. Alternatively, for example, electrolysis cell **18** can be configured to produce a greater volume of the anolyte stream compared to the catholyte stream if the

primary function of the electrochemically-activated water is sanitization. Also, the concentrations of reactive species in each can be varied.

[0039] For example, electrolysis cell **18** can have a 3:2 ratio of cathode plates (of cathode electrode **46**) to anode plates (of anode electrode **44**) for producing a greater volume of the catholyte stream compared to the anolyte stream. Each cathode plate is desirably separated from a respective anode plate by a respective barrier (e.g., an ion exchange membrane or diaphragm). Thus, in this embodiment, there are three cathode chambers **40** for two anode chambers **38**. This configuration produces roughly 60% catholyte to 40% anolyte. Other ratios can also be used as individual cleaning and/or sanitizing needs may require. In this embodiment, control electronics **14** may also periodically reverse the polarities of electrodes **44** and **46** to provide an overall 1:1 ratio of the catholyte to anolyte, or other ratios.

[0040] In addition, water molecules in contact with anode electrode **44** are electrochemically oxidized to oxygen ( $O_2$ ) and hydrogen ions ( $H^+$ ) in the anode chamber **38**, while water molecules in contact with the cathode electrode **46** are electrochemically reduced to hydrogen gas ( $H_2$ ) and hydroxyl ions ( $OH^-$ ) in cathode chamber **40**. The hydrogen ions in anode chamber **38** are allowed to pass through barrier **42** into cathode chamber **40** where the hydrogen ions are reduced to hydrogen gas while the oxygen gas in anode chamber **38** oxygenates the feed water to form the anolyte stream. Furthermore, since regular tap water typically includes sodium chloride and/or other chlorides, the anode electrode **44** oxidizes the chlorides present to form chlorine gas. As a result, a substantial amount of chlorine is produced and the pH of the anolyte stream becomes increasingly acidic over time.

[0041] As noted, water molecules in contact with cathode electrode **46** are electrochemically reduced to hydrogen gas and hydroxyl ions ( $OH^-$ ), while cations in the anode chamber **38** pass through barrier **42** into cathode chamber **40** when the voltage potential is applied. These cations are available to ionically associate with the hydroxyl ions produced at the cathode electrode **46**, while hydrogen gas bubbles form in the liquid. Substantial amounts of hydroxyl ions accumulate over time in cathode chamber **40** and react with cations to form basic hydroxides. In addition, the hydroxides remain confined to cathode chamber **40** since barrier **42** (i.e., a cation-exchange membrane) does not allow the negatively charged hydroxyl ions pass through. Consequently, substantial amounts of hydroxides are produced in cathode chamber **40**, and the pH of the catholyte stream becomes increasingly alkaline over time.

[0042] Accordingly, the electrolysis process in electrolysis cell **18** generates concentrations of reactive species and forms metastable ions and radicals in anode chamber **38** and cathode chamber **40**. The electrochemical activation process typically occurs by either electron withdrawal (at anode electrode **44**) or electron introduction (at cathode electrode **46**), which leads to alteration of physiochemical (including structural, energetic and catalytic) properties of the feed water. It is believed that the feed water becomes activated in the immediate proximity of the electrode surfaces where the electric field intensities can reach high levels.

[0043] In addition to electrochemical activation, the electrical current that is induced through electrolysis cell **18** also heats the streams flowing through anode chamber **38** and cathode chamber **40** of electrolysis cell **18**. This heating increases the temperatures of the resulting streams from an

initial inlet temperature of the feed water to an elevated temperature, which further increases the cleaning properties of the resulting streams.

[0044] In particular, the streams are primarily heated due to the electrical resistance of the water (or other liquid) when the electrical current is induced across electrolysis cell 18 (i.e., Joule heating). Pursuant to the Joule effect, the generated heat is proportional to the electrical resistance of the water times the square of the induced electrical current, as illustrated by Equation 1:

$$Q \sim I^2 \times R \quad (\text{Equation 1})$$

where "Q" is the energy produced, "I" is the induced electrical current across electrolysis cell 18, and "R" is the electrical resistance of the water (or other liquid) flowing through electrolysis cell 18.

[0045] This generated heat accordingly heats the water in a manner that is based on the flow rate of the streams, the specific heat capacity of the water, and the initial temperature of the water, as illustrated by Equation 2:

$$Q \sim M \times C \times (T_{out} - T_{initial}) \quad (\text{Equation 2})$$

where M is proportional to the flow rate of the streams through electrolysis cell 18, "C" is the specific heat capacity of the feed water (or other liquid), "T<sub>out</sub>" is the elevated temperature of the resulting outlet streams through outlet lines 48 and 50, and "T<sub>initial</sub>" is the initial temperature of the feed water entering electrolysis cell 18. Combining Equations 1 and 2 results in the relationship for heating the streams flowing through electrolysis cell 18, which is illustrated by Equation 3:

$$T_{out} \sim \frac{I^2 \times R}{M \times C} + T_{initial} \quad (\text{Equation 3})$$

As such, the elevated temperatures of the outlet streams from electrolysis cell 18 are proportional to the current induced through electrolysis cell 18, and inversely proportional to the flow rate of the streams through electrolysis cell 18.

[0046] In the shown embodiment, outlet lines 48 and 50 are respectively connected to temperature sensors 52 and 54, which are connected to control electronics 14 over electrical lines 56 and 58. This arrangement allows control electronics 14 to monitor the temperatures of the streams flowing through outlet lines 48 and 50. In one embodiment, control electronics 14 utilizes one or more process control loops to adjust the flow rate of pump 16 and/or the induced current through electrolysis cell 18 to maintain the temperatures of the streams flowing through outlet lines 48 and 50 at a predetermined temperature, above a predetermined minimum temperature, or within a predetermined temperature range.

[0047] For example, if temperature sensors 52 and 54 detect a temperature that falls below a predetermined minimum temperature, control electronics 14 may slow down pump 16 to decrease the flow rate of the feed water to electrolysis cell 18. This accordingly increases the residence time of the feed water streams through electrolysis cell 18, thereby increasing the exposure time for a particular volume of the streams to the induced electrical current. As illustrated above in Equation 3, this accordingly increases the temperatures of the outlet streams flowing through outlet lines 48 and 50.

[0048] Alternatively, or in addition, the voltage applied to electrolysis cell 18 may be increased to correspondingly

increase the induced electrical current. As also illustrated above in Equation 3, this also increases the temperatures of the outlet streams flowing through outlet lines 48 and 50. However, in comparison to decreasing the flow rate of the streams, the quadratic relationship of the induced electrical current allows a small increase in the applied voltage to substantially increase the resulting temperature of the outlet streams. Moreover, the quadratic relationship allows a small current and low flow rates to be utilized, which is particularly suitable for mobile floor cleaners and hand-held units.

[0049] Furthermore, varying the applied voltage rather than the flow rate allows the flow rate of the water through cleaning system 10 to be substantially constant. This is beneficial for maintaining a steady output rate of the thermally-enhanced treatment water from dispenser 20.

[0050] Examples of elevated temperatures for each of the streams flowing through outlet lines 48 and 50 (and dispenser 20) include temperatures of at least about 75° F., with particularly suitable temperatures ranging from about 85° F. to about 130° F., and with even more particularly suitable temperatures ranging from about 95° F. to about 110° F. It is found that increased temperatures of the outlet streams increase the cleaning capabilities of cleaning system 10a.

[0051] The elevated temperatures of the streams flowing through outlet lines 48 and 50 may alternatively be referred to based on the temperature increase or change relative to the inlet temperature of the feed water entering electrolysis cell 18 (i.e., T<sub>out</sub> - T<sub>initial</sub>). Examples of suitable temperature increases include increases from about 5° F. or more, with particularly suitable temperature increases ranging from about 15° F. to about 60° F., and with even more particularly suitable temperature increases ranging from about 25° F. to about 40° F.

[0052] Examples of suitable flow rates of the feed water into electrolysis cell 18 range from about 0.1 gallons/minute to about 1.0 gallon/minute, with particularly suitable flow rates ranging from about 0.1 gallons/minute to about 0.5 gallons/minute, and with even more particularly suitable flow rates ranging from about 0.1 gallons/minute to about 0.3 gallons/minute.

[0053] Examples of suitable voltages applied across electrolysis cell 18 range from about 5 volts to about 40 volts, and suitable induced electrical currents include currents of about 1.0 ampere or less. As mentioned above, control electronics 14 can provide a constant DC output voltage, a pulsed or otherwise modulated DC output voltage, or a pulsed or otherwise modulated AC output voltage to electrodes 44 and 46 of electrolysis cell 18. In one embodiment, control electronics 14 may apply the voltage supplied to electrodes 44 and 46 at a relative steady state. In this embodiment, control electronics 14 and/or electrical source 22 includes a DC/DC converter that uses a pulse-width modulation (PWM) control scheme to control voltage and current output.

[0054] For example, the DC/DC converter may use a pulse of about 15 kilohertz to produce the desired voltage to electrodes 44 and 46 in the range of about 5 volts to about 40 volts, such as a voltage of 15 volts with a power up to about 500 watts. In some embodiments, suitable power levels range from about 120 watts to about 300 watts. In other embodiments, suitable power levels range from about 120 watts to about 150 watts. The duty cycle is dependent on desired voltage and current output. For example, the duty cycle of the DC/DC converter can be 90%. Control electronics 14 and/or electrical source 22 can also be configured, if desired, to

alternate the voltage applied to electrolysis cell **18** between a relative steady state voltage at one polarity and then a relative steady state voltage at the opposite polarity for equal time periods (e.g., 5 seconds each), or different time periods to bias towards anolyte or catholyte liquids.

[0055] Outlet lines **48** and **50** connect to dispenser **20** for dispensing one or both of the acidic anolyte stream and the basic catholyte stream at the elevated temperatures. For example, one or both of outlet lines **48** and **50** may include valves (not shown) for optionally directing the streams from either outlet line **48** or outlet line **50** through recovery line **60** to recovery tank **62** (illustrated with broken lines). This allows dispenser **20** to selectively dispense either or both of the thermally-enhanced anolyte stream or the thermally-enhanced catholyte stream based on desired cleaning and/or sanitizing purposes.

[0056] Dispenser **20** may be any suitable dispenser component, such as a spray dispenser, for example. Dispenser **20** may also include one or more scrubbing components (not shown) to assist in the cleaning operation. For example, dispenser **20** may include one or more brushes, such as bristle brushes, pad scrubbers, microfibers, or other hard (or soft) floor surface scrubbing elements (not shown). As mentioned above, during operation, cleaning system **10a** may generate the thermally-enhanced anolyte stream and the thermally-enhanced catholyte stream in an on-demand manner, each or both of which can be dispensed from dispenser **20** for cleaning. In one embodiment, cleaning system **10a** dispenses substantially all of the thermally-enhanced anolyte and catholyte streams without intermediate storage of either the anolyte stream or catholyte stream, and without feedback of any of the anolyte stream or catholyte stream into electrolysis cell **18**.

[0057] As can be appreciated, the above-discussed suitable flow rates, voltage, and current ranges may quickly heat the feed water from its initial temperature (e.g., about 70° F.) to the elevated temperature. This, combined with an on-demand activation of pump **16** and electrolysis cell **18**, is beneficial for quickly supplying electrochemically-activated water to dispenser **20** at the elevated temperature for cleaning surfaces.

[0058] This combination is particularly suitable for use in mobile cleaning systems. Conventional mobile cleaning systems are typically pre-filled with a liquid, such as tap water, well in advance of their use. For example, after a cleaning operation, a user may fill the mobile cleaning system with tap water for use during the next day. Maintaining the water at the elevated temperature during the overnight period requires a substantial amount of power that becomes expensive over an extended period of time. Alternatively, the pre-filled water in such systems may be heated immediately prior to use. However, this creates a lag time before the given mobile cleaning system can be used.

[0059] Instead, cleaning system **10a** can be pre-filled with any suitable liquid (e.g., tap water), allowed to sit overnight, and heat the liquid in an on-demand manner in electrolysis cell **18**. This quickly heats the liquid streams while also electrochemically activating the liquid streams to produce a thermally-enhanced anolyte stream and a thermally-enhanced catholyte stream, each or both of which can be dispensed from dispenser **20** for cleaning surfaces.

[0060] FIGS. 2-5 illustrate systems **10b-10e**, which are alternative cleaning systems to cleaning system **10a** (shown in FIG. 1) for generating thermally-enhanced, electrochemi-

cally-activated liquids. As shown in FIG. 2, system **10b** is similar to system **10a**, where outlet lines **48** and **50** converge to combined outlet line **64**.

[0061] As described in Field et al. U.S. Patent Publication No. 2007/0186368, it has been found that the anolyte and catholyte streams can be blended together within the distribution system of a cleaning apparatus and/or on the surface or item being cleaned while at least temporarily retaining beneficial cleaning and/or sanitizing properties. Although the anolyte and catholyte streams are blended, they are initially not in equilibrium and therefore temporarily retain their enhanced cleaning and sanitizing properties. In the embodiment shown in FIG. 2, because each stream is heated in electrolysis cell **18** to the elevated temperature, the combined streams at combined outlet line **64** may retain the elevated temperature for dispensing via dispenser **20**.

[0062] FIG. 3 illustrates cleaning system **10c**, which is similar to cleaning systems **10a** and **10b**. In this embodiment, however, electrolysis cell **18** is replaced with electrolysis cell **66** having a single reaction chamber **68** for anode electrode **44** and cathode electrode **46** (i.e., no barrier **42**). As such, feed line **32** and outlet line **70** directly connect to reaction chamber **68**.

[0063] During operation, water (or other liquid) is introduced into reaction chamber **68**, and a voltage potential is applied between electrodes **44** and **46**. This causes water molecules in contact with or near anode electrode **44** electrochemically oxidize to oxygen ( $O_2$ ) and hydrogen ions ( $H^+$ ), while water molecules in contact or near cathode electrode **46** are electrochemically reduce to hydrogen gas ( $H_2$ ) and hydroxyl ions ( $OH^-$ ). Other reactions can also occur and the particular reactions depend on the components of the water. The reaction products from both electrodes **44** and **46** are able to mix and form an oxygenated fluid (for example) since there is no physical barrier separating the reaction products from each other.

[0064] Omitting a barrier between electrodes **44** and **46** allows the flowing water to heat in a uniform manner, as opposed to heating separate streams. This accordingly can increase the heating rate of the water flowing through electrolysis cell **66**.

[0065] FIG. 4 illustrates cleaning system **10d**, which is also similar to cleaning systems **10a-10c**. In this embodiment, cleaning system **10d** also includes a separate additional heating element **72** located downstream from outlet line **70**, and controlled by control electronics **14** over electrical line **73**. Heating element **72** may be any suitable heat-exchange component for further heating the electrochemically-activated water from electrolysis cell **66**. For example, heating element **72** may be a metallic coil retained within the walls of outlet line **70** to conductively heat the electrochemically-activated water to a desired elevated temperature.

[0066] Cleaning system **10d** also includes outlet line **74** between heating element **72** and dispenser **20**, and temperature sensor **76**, which allows control electronics **14** to monitor the temperature of the electrochemically-activated water flowing through outlet line **74** (via electrical connection **78**). The use of heating element **72** provides control electronics **14** even greater control over the heating profile of the feed water.

[0067] FIG. 5 illustrates cleaning system **10e**, which is also similar to cleaning system **10d**, where heating element **72** and temperature sensor **76** are located upstream from electrolysis cell **66** (e.g., between pump **16** and electrolysis cell **66**). In this embodiment, heating element **72** may be used to heat the

feed water to a desired temperature prior to the electrolysis reaction in electrolysis cell 66. Pre-heating the feed water prior to electrolysis in an electrolysis cell (e.g., electrolysis cell 66) reduces the electrical current required to electro-chemically activate the feed water. For example, when heating elements 72 heats the feed water to an elevated temperature (e.g., 100° C.), electrolysis cell 66 may operate with lower induced electrical currents, such as about 0.5 amperes or less, and even 0.3 amperes or less, for the same applied voltages (e.g., from about 5 volts to about 40 volts). This may reduce scaling issues in electrolysis cell 66.

[0068] FIG. 6 illustrates cleaning system 10f, which is another alternative to cleaning system 10d, in which electrolysis cell 66 is omitted. In this embodiment, the feed water is heated from its initial temperature to the desired elevated temperature with the use of heating element 72.

[0069] The cleaning systems of the present disclosure (e.g., cleaning systems 10a-10f) are suitable for use in a variety of cleaning environments, such as industrial, commercial, and residential environments. This is particularly true with cleaning systems 10a-10e, which also electrochemically activate the feed liquids.

[0070] In one embodiment, the present disclosure is directed to a method of using a cleaning system (e.g., cleaning systems 10a-10f) in cold-room cleaning environments, such as food processing rooms that require cold temperatures (e.g., below 0° C.). Conventional cleaning systems that operate in cold rooms typically require additives (e.g., glycols) in their cleaning solutions to prevent the cleaning solutions from freezing in the cold rooms. The cleaning systems of the present disclosure, however, heat the feed water prior to dispensing. This reduces or eliminates the need for such additives, which can otherwise leave residues if not properly removed. Accordingly, in this embodiment, the feed liquid is desirably free or substantially free of glycol-based compositions.

[0071] The method includes the steps of pumping a feed liquid at room temperature (e.g., 25° C.) from a liquid source to an electrolysis cell, electrochemically activating and heating the feed liquid in the electrolysis cell (and optionally heating with an additional heating element) to provide an electrochemically-activated liquid at an elevated temperature, and dispensing the electrochemically-activated liquid to a surface in a cold-room environment.

[0072] FIGS. 7A-7C illustrate a mobile hard floor surface cleaner 100 in accordance with one or more exemplary embodiments of the present disclosure, and may include the components of one or more of cleaning systems 10a-10f (shown in FIGS. 1-6). Further discussion of suitable components for cleaner 100 are disclosed in Field et al., U.S. Patent Application Publication No. 2007/0186368, the disclosure of which is incorporated by reference.

[0073] In one example, cleaner 100 is substantially similar to the Tennant T5 Scrubber-Dryer equipped with the equipment under the "EC-H2O" Technology from Tennant Company, Minneapolis, Minn., for example, which has been modified to include the components and/or operating characteristics discussed above for one or more of cleaning systems 10a-10f (shown in FIGS. 1-6).

[0074] In this example, cleaner 100 is a walk-behind cleaner used to clean hard floor surfaces, such as concrete, tile, vinyl, terrazzo, etc. Alternatively, for example, cleaner 100 can be configured as a ride-on, attachable, or towed-behind cleaner for performing a scrubbing operation as

described herein. In a further example, cleaner 100 can be adapted to clean soft floors, such as carpet, or both hard and soft floors in further embodiments. Cleaner 100 may include electrical motors powered through an on-board power source, such as batteries, or through an electrical cord. Alternatively, for example, an internal combustion engine system could be used either alone, or in combination with, the electric motors.

[0075] Cleaner 100 generally includes a base 102 and a lid 104, which is attached along one side of the base 102 by hinges (not shown) so that lid 104 can be pivoted up to provide access to the interior of base 102. Base 102 includes a tank 106 for containing a feed liquid or a primary cleaning and/or sanitizing liquid component (such as regular tap water) to be treated and applied to the floor surface during cleaning/sanitizing operations. Alternatively, for example, the liquid can be treated onboard or offboard cleaner 100 prior to containment in tank 106. Tank 106 can have any suitable shape within base 102, and can have compartments that at least partially surround other components carried by base 102.

[0076] Base 102 carries a motorized scrub head 110, which includes one or more scrubbing members 112, shrouds 114, and a scrubbing member drive 116. Scrubbing member 112 may include one or more brushes, such as bristle brushes, pad scrubbers, microfibers, or other hard (or soft) floor surface scrubbing elements. Drive 116 includes one or more electric motors to rotate the scrubbing member 112. Scrubbing members 112 may include a disc-type scrub brush rotating about a generally vertical axis of rotation relative to the floor surface, as shown in FIGS. 7A-7C.

[0077] Alternatively, for example, scrubbing members 112 may include one or more cylindrical-type scrub brushes rotating about a generally horizontal axis of rotation relative to the hard floor surface. Drive 116 may also oscillate scrubbing members 112. Scrub head 110 may be attached to cleaner 100 such that scrub head 110 can be moved between a lowered cleaning position and a raised traveling position. Alternatively, for example, cleaner 100 can include no scrub head 110 or scrub brushes.

[0078] Base 102 further includes a machine frame 117, which supports source tank 106 on wheels 118 and castors 119. Wheels 118 are driven by a motor and transaxle assembly, shown at 120. The rear of the frame carries a linkage 121 to which a fluid recovery device 122 is attached. In the embodiment of FIGS. 7A-7C, the fluid recovery device 122 includes a vacuum squeegee 124 that is in vacuum communication with an inlet chamber in recovery tank 108 through a hose 126. The bottom of source tank 106 includes a drain 130, which is coupled to a drain hose 132 for emptying source tank 106. Similarly, the bottom of recovery tank 108 includes a drain 133, which is coupled to a drain hose 134 for emptying recovery tank 108. Alternatively, for example, one or both of the source tank and recovery tank and related systems can be housed in or carried by a separate apparatus.

[0079] In a further exemplary embodiment, the fluid recovery device includes a non-vacuumized mechanical device for lifting the soiled solution away from the floor surface and conveying the soiled solution toward a collection tank or receptacle. The non-vacuumized mechanical device can include, for example, a plurality of wiping media such as pliable material elements, which are rotated into contact with the floor surface to engage and lift the soiled solution from the floor surface.

[0080] In a further embodiment, cleaner 100 is equipped without a scrub head, wherein the liquid is dispensed to floor

125 for cleaning or sanitizing without a scrubbing action. Subsequently, fluid recovery device 122 recovers at least part of the dispensed liquid from the floor. In another embodiment, cleaner 100 includes a wand sprayer and extractor or other attachment (not shown) that can be used to clean off floor surfaces.

[0081] Cleaner 100 can further include a battery compartment 140 in which batteries 142 reside. Batteries 142 provide power to drive motors 116, vacuum fan or pump 144, and other electrical components of cleaner 100. Vacuum fan 144 is mounted in the lid 104. A control unit 146 mounted on the rear of the body of cleaner 100 includes steering control handles 148 and operating controls and gages for cleaner 100.

[0082] Liquid tank 106 is a liquid source (e.g., liquid source 20) filled with a feed liquid to be treated for cleaning and/or sanitizing use, such as regular tap water. In one embodiment, the feed liquid is free or substantially free of any surfactant, detergent or other cleaning chemical. Cleaner 100 further includes an output fluid flow path 160, which includes a pump 164 (corresponding to pump 14) and electrolysis cell 162 (corresponding to electrolysis cells 18 and 66).

[0083] Liquid tank 106, electrolysis cell 162, and pump 164 can be positioned anywhere on cleaner 100. In one embodiment, electrolysis cell 162 is mounted within a housing 150 that is carried within base 102. Pump 164 is mounted beneath source tank 106 and pumps water from tank 106 along flow path 160, through electrolysis cell 162 to the vicinity of scrub head 110 and ultimately to floor 125, wherein recovery device 122 recovers the soiled liquid and returns it to recovery tank 108.

[0084] The arrows in FIG. 7A illustrate the direction of liquid flow from tank 106, through flow path 160, to floor 125 and then from recovery device 122 to recovery tank 128. In one embodiment, electrolysis cell 162 is located adjacent to scrub head 110 to reduce the length of flow path 160. Alternatively, flow path 160 may be thermally insulated to reduce heat loss as the thermally-enhanced, electrochemically-activated liquid flows from electrolysis cell 162 to scrub head 110. In further alternative embodiments, flow path 160 may also include one or more heating elements (not shown) corresponding to heating element 72 (shown in FIGS. 4-6).

[0085] In one embodiment of the disclosure, the control unit 146 is configured to operate pump 164 and electrolysis cell 162 in an "on demand" fashion, as discussed above. Pump 164 is in an "off" state and electrolysis cell 162 is de-energized when cleaner 100 is at rest and not moving relative to the floor being cleaned. Control unit 146 switches pump 164 to an "on" state and energizes electrolysis cell 162 when cleaner 100 travels in a forward direction relative to the floor, as indicated by arrow 165. In the "on" state, pump 164 pumps water from tank 106 through flow path 160 to the vicinity of scrub head 110. Thus, electrolysis cell 162 generates and delivers the thermally-enhanced, electrochemically-activated water "on demand", as discussed above. For example, cleaner 100 may dispense substantially all of the thermally-enhanced anolyte and catholyte streams without intermediate storage of either the anolyte stream or catholyte stream, and without feedback of any of the anolyte stream or catholyte stream into electrolysis cell 162.

[0086] As described in more detail below, flow path 160 can include a single, combined output flow path for the heated and blended catholyte and anolyte electrochemically-activated water produced at the output of electrolysis cell 162 or can include separate paths that can combine somewhere along

flow path 160 or at the dispenser or remain separate along the entire length of flow path 160. The separate flow streams can have a common fluid dispenser near scrub head 110 or can be routed to separate liquid dispensers. Pump 164 can represent a single pump or multiple pumps for multiple flow paths.

[0087] In an embodiment in which cleaner 100 is configured to selectively dispense one or both the anolyte or catholyte electrochemically-activated water outputs, cleaner 100 can also include one or more waste water flow paths from electrolysis cell 162 for routing unused catholyte or anolyte water from housing 150 to recovery tank 108 or a separate waste water tank. A flow path can also be provided for routing unused catholyte or anolyte to a buffer or reservoir (not shown in FIGS. 7A-7C) for later use by cleaner 100. For example if cleaner 100 is operated in a cleaning only mode, the anolyte water produced by electrolysis cell 162 may not be needed and can be routed to recovery tank 108 or to a buffer or separate storage tank for later use, such as in a disinfecting operating mode.

[0088] If cleaner 100 is operated in a disinfecting only mode, the catholyte water produced by electrolysis cell 162 may not be needed and can be routed to recovery tank 108 or to a buffer or separate storage tank for later use, such as in a cleaning operating mode. In a cleaning and disinfecting operating mode, both the catholyte water and the anolyte water are routed along flow path 160 to be applied to the floor either simultaneously or sequentially. The catholyte water can be applied to the floor surface to clean the floor surface and then removed prior to application of the anolyte water to the same floor surface for disinfecting purposes. The catholyte and anolyte water can also be applied in a reverse order. Alternatively, for example, cleaner 100 can be configured to apply intermittently catholyte water for a short period of time followed by application of anolyte water, or vice versa. The various operating modes that control whether catholyte and/or anolyte water are applied and at what times, concentrations, flow rates and can be controlled by the operator through control unit 146.

[0089] In a further embodiment, cleaner 100 can be modified to include two separate cleaning heads, one for dispensing and recovering anolyte water and one for dispensing and recovering catholyte water. For example, each head would include its own liquid dispenser, scrub head and squeegee. One can follow the other along the travel path of the cleaner. For example, the leading head can be used for cleaning, while the trailing head can be used for sanitizing.

[0090] As mentioned above, it has been found that when the two liquids streams containing the thermally-enhanced anolyte water and the thermally-enhanced catholyte water are applied to the surface being cleaned at the same time, either through a combined output stream or separate output streams, the two liquids, although blended or combined on the surface, retain their individual enhanced cleaning and sanitizing properties during a typical resident time on the surface. For example, as cleaner 100 advances at a typical rate across the surface being cleaned, the residence time on the surface between distribution to the surface and then recovery by vacuum squeegee 124 is relatively short, such as about three seconds.

[0091] In one example, the catholyte water and the anolyte water maintain their distinct electrochemically activated properties for at least 30 seconds, for example, even though the two liquids are blended together. During this time, the distinct electrochemically activated properties of the two

types of liquids do not neutralize until after the liquid has been recovered from the surface. This allows the advantageous properties of each liquid to be utilized during a common cleaning operation. After recovery, the nanobubbles begin to diminish and the alkaline and acidic liquids begin to neutralize. Once neutralized, the electrochemical properties, including the pH, of the recovered, blended liquid reverts to those of regular tap water.

[0092] Electrolysis cell 162 can be powered by batteries 142 or by one or more separate power supplies that are powered by or independent of batteries 142 and adapted to provide the electrodes with the desired voltage and current levels in a desired waveform.

[0093] The liquid distribution path of cleaner 100 can also include, if desired, one or more filters for removing selected components or chemicals from the feed water or the produced EA water to reduce residue left on the surface being cleaned. The path can also include an ultraviolet (UV) radiation generator for UV-treating the liquid to reduce viruses and bacteria in the liquid.

[0094] FIG. 8 is a block diagram illustrating the liquid distribution flow path 160 of cleaner 100 in greater detail according to an embodiment of the disclosure. For simplicity, the wastewater flow path to recovery tank 108 and other components of cleaner 100 are not illustrated in FIG. 8. The elements in flow path 160 can be rearranged upstream or downstream relative to one another in other embodiments. Also, the particular elements along flow path 160 may vary from one embodiment to the next, depending upon the particular application and platform being implemented. Furthermore, one or more of the elements in the block diagram may be omitted, such as recovery tank 108.

[0095] The liquid or feed water in tank 106 is coupled to the input of electrolysis cell 162 through conduit sections 170 and 171, and pump 164. Pump 164 can include any suitable type of pump, such as a diaphragm pump.

[0096] As discussed above, an additive or boosting compound, such as an electrolyte (e.g., sodium chloride) or other compound, can be added to the feed water at any desired concentration and at any desired location along the flow path upstream of electrolysis cell 162. For example, the additive can be added to the water within tank 106. In a further example, an additive flow-through device 173 can be coupled in-line with the flow path, such as downstream (or upstream) of pump 164 for inserting the additive into the feed water. However, such an additive is not required for many cleaning applications and types of liquid, such as regular tap water. In some applications an additive can be used to further boost the respective pH values of the anolyte and catholyte outputs of electrolysis cell 162 even further away from a neutral pH, if desired.

[0097] In applications in which an additional detergent is desired, cleaner 100 can be modified to further include a source 180 of a cleaning agent, which is supplied to the input of electrolysis cell 162 through conduit sections 181 and 182, and pump 183 (all shown in dashed lines). Alternatively, for example, pump 183 can supply the cleaning agent to one or more of the flow paths 160 downstream of electrolysis cell 162 or to the flow path upstream of pump 164, for example. Mixing member 184 mixes the supplied cleaning agent with the feed water from liquid source 106.

[0098] The flow of cleaning agent is generated substantially independently of the volume of cleaning agent in supply 180. A check valve (not shown) can be installed in line with

conduit section 170 to prevent the back flow of cleaning agent and primary cleaning liquid component to tank 106 when fluid mixing member 184 is upstream of pump 164. Pump 183 can include any suitable pump, such as a solenoid pump.

[0099] Controller 186 (shown in dashed lines) controls the operations of pump 183 through a control signal 187 line. In accordance with one embodiment, signal line 187 may carry a pulsed signal that provides power relative to ground (not shown) and controls the duration over which the pump drives the cleaning agent through conduit 182. For example, control signal 187 can turn pump 183 on for 0.1 seconds and off for 2.75 seconds to produce a low volume output flow of concentrated cleaning agent. Other on/off times can also be used. In addition, pumps 164 and 183 can be eliminated and the liquid and cleaning agent can be fed by another mechanism, such as gravity. In the example shown in FIGS. 7A-7C, cleaner 100 does not include elements 180, 183, 184 and 186 since no additional cleaning agent is used.

[0100] Electrolysis cell 162 has a catholyte water output or outlet line 190 and an anolyte water output or outlet line 192, which are combined into a common flow path 160 (shown in solid lines) and fed to a fluid dispenser 194. In another embodiment of the disclosure, flow path 160 includes a separate flow path 160A and 160B (shown in dashed lines) for each output line 190 and 192. The relative flows through the individual or combined flow paths can be controlled through one or more valves or other flow control devices 195 placed along the paths.

[0101] Buffers or reservoirs 196 can be placed along paths 160, 160A and/or 160B to collect any catholyte or anolyte produced by electrolysis cell 162 but not immediately delivered to fluid dispenser 194. For example, reservoirs 196 can include a burp valve, which allows the reservoir to fill, then once filled, empty into the respective flow path for use. Other types of reservoirs and valve or baffle systems can also be used. The two reservoirs 196 can be controlled to open or empty alternately, simultaneously, or on any other interval or control signal. If one of the catholyte or anolyte is not being used for a particular cleaning or sanitizing operation, the excess unused liquid can be supplied to recovery tank 108, through valves 195. Alternatively, for example, the liquid can be supplied to a separate storage tank for later use. A separate storage tank can also be used, for example, in embodiments in which the output flow rate of the dispenser exceeds the rate at which one or more of the elements in the flow path can treat the liquid to be dispensed effectively.

[0102] In accordance with another embodiment of the disclosure, one or more flow restriction members 198 can be placed in line with flow paths 160, 160A and/or 160B to regulate the flow of liquid if desired or needed for a particular configuration. For example, a pressure drop across flow restriction members 198 can restrict the flow of fluid to provide the desired volume flow rate. For example, a flow restriction member 198 can include a metering orifice or orifice plate that provides a desired output flow, such as of 0.2 GPM when the pressure of outlet of pump 164 is at approximately 40 psi. Other flow rates greater than or less than 0.2 GPM can also be used.

[0103] If a supply of cleaning agent is used, the volume flow rate of cleaning agent can be limited by pump 183 to approximately 10 cubic centimeters or less per minute, for example. Examples of elements and methods for controlling the volume flow rates of the liquid and the cleaning agent are described in more detail in U.S. Pat. No. 7,051,399. However,

these elements and methods are not required in one or more embodiments of the present disclosure.

[0104] Cleaner 100 can further include one or more heating elements 163 along combined flow path 160 or along one or both the separate flow paths 160A and 160B, downstream of electrolysis cell 162. Heating element(s) 163 can be located anywhere along flow paths 160, 160A and 160B between electrolysis cell 162 and fluid dispenser 194. As discussed above, cleaner 100 may alternatively (or additionally) include one or more heating elements (not shown) located upstream from electrolysis cell 162.

[0105] Flow paths 160, 160A and/or 160B can further include pressure relief valves 202 and check valves 204, which can be located at any suitable position along any flow path in cleaner 100. Check valves 204 can help to limit leakage of liquid when cleaner 100 is not in use. Cleaner 100 may also include one or more sparging devices (not shown) located upstream and/or downstream from electrolysis cell 162 and/or heating element(s) 163. Examples of suitable sparging devices for use in cleaner 100 (and cleaning systems 10a-10f) include those disclosed in Field et al., U.S. Patent Application Publication No. 2007/0186368.

[0106] Fluid dispenser 194 can include any suitable distribution elements for the particular application in which cleaner 100 is used. For example in one embodiment, fluid dispenser 194 directs the liquid to the hard floor surface or to another component of cleaner 100, such as a scrub head. In the case in which the scrub head has multiple brushes, fluid dispenser 194 can include a T-coupling, for example, can be used to route separate output streams to each brush, if desired. The liquid can be dispensed in any suitable manner, such as by spraying or dripping.

[0107] In embodiments in which the anolyte and catholyte are applied separately from one another, fluid dispenser 194 can have separate outputs, one for each type of liquid. Alternatively, for example, fluid dispenser can have a single output, where the flow from each flow path is controlled by a valve, switch or baffle, for example. In a further embodiment, fluid dispenser 194 includes a flow control device that selectively passes the anolyte only, the catholyte only or a mixture of the anolyte and catholyte. The terms fluid dispenser and liquid dispenser can include, for example, a single dispensing element or multiple dispensing elements whether or not those elements are connected together.

[0108] It has been found that when the two liquids streams containing the anolyte water and the catholyte water are applied to the surface being cleaned at the same time, either through a combined output stream or separate output streams, the two liquids, although blended on the surface, retain their individual enhanced cleaning and sanitizing properties during a typical resident time on the surface. For example, when cleaner 100 advances at a typical rate across the surface being cleaned, the residence time on the surface between distribution to the surface and then recovery by vacuum squeegee 124 (shown in FIG. 7A) is relatively short, such as about 2-3 seconds. During this time, the distinct electrochemical activation properties of the two types of liquid do not neutralize until after the liquid has been recovered from the surface. This allows the advantageous properties of each liquid to be utilized during a common cleaning operation. This is in addition to the increased cleaning attained by the thermal enhancement of the liquids.

[0109] After recovery, the nanobubbles begin to diminish and the alkaline and acidic liquids begin to neutralize. Once

neutralized, the electrochemical properties, including the pH, of the recovered, blended liquid reverts to those of regular tap water. This allows the oxidation-reduction potential and other beneficial cleaning/sanitizing properties of a blended water to be substantially retained during the residence time before these properties substantially neutralize in the recovery tank of the cleaner or following disposal.

[0110] Also, it has been found that the oxidation-reduction potential and other electrochemically activated properties of the blended water (or other electrochemically-activated liquid) neutralize relatively quickly in the recovery tank after recovery. This allows the recovered liquid to be disposed of almost immediately after a cleaning operation has been completed without having to wait or store the recovered liquid in a temporary disposal tank until the liquid neutralizes.

[0111] In further alternative embodiments, the cleaning systems of the present disclosure may be provided as hand-held units, such as spray bottles. In these embodiments, cleaning systems 10a-10f may function as hand-held units, such as those disclosed in Field, U.S. Patent Application Publication No. 2009/0314658; and Field, U.S. Patent Application Publication No. 2010/0147701, the disclosures of each of which are incorporated by reference. Additional suitable hand-held units include those commercially available under the trade designations "IONATOR HOM" and "IONATOR EXP" from Activeion Cleaning Solutions, LLC, Minneapolis, Minn. For example, the hand-held cleaning unit may include one or more heating elements located upstream and/or downstream from the electrolysis cell(s), where the heating element(s) and the electrolysis cell(s) may be operated in on-demand applications.

## EXAMPLES

[0112] The present disclosure is more particularly described in the following examples that are intended as illustrations only, since numerous modifications and variations within the scope of the present disclosure will be apparent to those skilled in the art. Unless otherwise noted, all parts, percentages, and ratios reported in the following examples are on a weight basis, and all reagents used in the examples were obtained, or are available, from the chemical suppliers described below, or may be synthesized by conventional techniques.

[0113] A cleaning system of the present disclosure (Example 1) and a comparative cleaning system (Comparative Example A) were operated to compare their cleaning capabilities on soiled test strips. The soiled test strips included uniform coatings of various soiling compositions that are typical in light industrial settings, retail environments (e.g., as in food courts), food preparation settings, and public dining areas. The same soiling compositions were used for direct comparisons of the cleaning runs between the cleaning system of Example 1 and the cleaning system of Comparative Example A. The cleaning system of Example 1 and the cleaning system of Comparative Example A were also operated side-by-side for direct comparisons of their cleaning capabilities.

[0114] The cleaning system of Example 1 included a feed source of tap water, an electrolysis cell, a downstream heating element, and a dispensing sprayer. The electrolysis cell was commercially available under the trade designation "eH2O" Electrically Converted Water Technology from Tenant Company, Minneapolis, Minn. During operation, the tap

water was pumped through the electrolysis cell, the heating element, and the dispensing sprayer.

[0115] The electrolysis cell electrochemically activated the tap water and increased the temperature of the water by several degrees. The alkaline stream of the electrochemically-activated water was then directed through the heating element, which further heated the electrochemically-activated water to about 125° F. during steady-state operation. The resulting heated, alkaline water was then lightly sprayed from the dispensing sprayer onto soiled test strips.

[0116] The cleaning system of Comparative Example A included an alkaline water (pH of 10.5), which was maintained at about 75° F. During operation, the alkaline water was fed to a dispensing sprayer, which was the same model as the dispensing sprayer in the cleaning system of Example 1. The resulting water was then lightly sprayed onto soiled test strips at the same rate as that used in the cleaning system of Example 1.

[0117] During each cleaning run, the cleaning system of Example 1 removed more of the soiling composition from its soiled test strip compared to the cleaning system of Comparative Example A. Because both cleaning systems sprayed an alkaline water onto their respective soiled test strips, it is believed that the elevated temperature of the sprayed alkaline water from the cleaning system of Example 1 attributed to the increased cleaning capabilities. As such, the combination of the electrochemical activation and the thermal enhancement provided a suitable treatment liquid for cleaning a variety of surfaces.

[0118] Although the present disclosure has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the disclosure.

**1. A cleaning system comprising:**

a liquid source configured to provide a feed liquid at a first temperature;  
an electrolysis cell configured to receive the feed liquid and to electrochemically activate the feed liquid to provide an electrochemically-activated liquid, wherein the electrochemical activation also heats the feed liquid such that the electrochemically-activated liquid is at a second temperature that is greater than the first temperature; and  
a dispenser configured to dispense the electrochemically-activated liquid.

**2. The cleaning system of claim 1, and further comprising** a heating element disposed upstream from the electrolysis cell, the heating element being configured to heat the feed liquid from the first temperature to a second temperature, and further configured to provide the heated feed liquid to the electrolysis cell.

**3. The cleaning system of claim 1, and further comprising** a heating element disposed downstream from the electrolysis cell, the heating element being configured to heat the electrochemically-activated liquid from the elevated temperature to a second temperature that is greater than the elevated temperature, and further configured to provide the heated electrochemically-activated liquid to the dispenser.

**4. The cleaning system of claim 1, and further comprising:**  
a mobile cleaning unit housing;  
a plurality of wheels configured to move the mobile cleaning unit housing; and

a drive motor retained within the mobile cleaning unit housing, and configured to rotate at least a portion of the plurality of wheels.

**5. The cleaning system of claim 1, and further comprising** a hand-held unit housing.

**6. The cleaning system of claim 1, wherein** the electrolysis cell comprises an anode electrode and a cathode electrode, and wherein the cleaning system further comprises control electronics configured to relay electrical power to the anode electrode and a cathode electrode.

**7. The cleaning system of claim 6, wherein** the electrolysis cell further comprises a barrier disposed between the anode electrode and the cathode electrode.

**8. The cleaning system of claim 1, and further comprising:**  
a fluid line interconnecting the electrolysis cell and the dispenser;

**a temperature sensor disposed along the fluid line, the temperature sensor being configured to measure temperatures of the electrochemically-activated liquid; and** control electronics configured to relay electrical power to the electrolysis cell based at least in part on the temperatures measured by the temperature sensor.

**9. A method for cleaning a surface, the method comprising:**  
pumping a feed liquid having a first temperature from a liquid source to an electrolysis cell;  
electrochemically activating and heating the feed liquid in the electrolysis cell to provide an electrochemically-activated liquid at an elevated temperature that is greater than the first temperature; and  
dispensing the electrochemically-activated liquid to the surface.

**10. The method of claim 9, and further comprising** heating the feed liquid with a heating element located upstream from the electrolysis cell.

**11. The method of claim 9, and further comprising** further heating the electrochemically-activated liquid with a heating element located downstream from the electrolysis cell.

**12. The method of claim 9, wherein** the surface is a surface in a cold-room environment, and wherein the feed liquid is substantially free of glycol-based compositions.

**13. The method of claim 9, and further comprising** monitoring temperatures of the electrochemically-activated liquid before dispensing the electrochemically-activated liquid to the surface.

**14. The method of claim 13, and further comprising** adjusting electrical power to the electrolysis cell based at least in part of the monitored temperatures.

**15. A method for cleaning a surface, the method comprising:**

pumping a feed liquid from a liquid source to an electrolysis cell;  
inducing a current through the electrolysis cell to electrochemically activate and heat the feed liquid in the electrolysis cell to provide an electrochemically-activated liquid;  
directing at least a portion of the electrochemically-activated liquid through a fluid line;  
monitoring a temperature of the electrochemically-activated liquid in the fluid line;  
controlling at least one of the pumping and the inducing of the current in response to the monitored temperature; and  
dispensing the at least one portion of the electrochemically-activated liquid to the surface.

**16.** The method of claim **15**, and further comprising heating the feed liquid with a heating element located upstream from the electrolysis cell.

**17.** The method of claim **15**, and further comprising further heating the electrochemically-activated liquid with a heating element located downstream from the electrolysis cell, wherein the fluid line at which the temperature of the electrochemically-activated liquid is monitored is located downstream from the heating element.

**18.** The method of claim **15**, wherein controlling at least one of the pumping and the inducing of the current in response to the monitored temperature maintains the temperature of the portion of the electrochemically-activated liquid directed through the fluid line within a predetermined temperature range.

**19.** The method of claim **15**, wherein the surface is a surface in a cold-room environment, and wherein the feed liquid is substantially free of glycol-based compositions.

**20.** The method of claim **15**, wherein the feed liquid consists essentially of water.

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