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(54) **Title**: REMOVAL OF DISSOLVED SALTS USING A SOLVENT

(57) **Abstract**: The present disclosure is related to a method and apparatus for reducing a salt concentration in a liquid composition using a solvent. The method includes combining the liquid composition and the solvent, where the solvent has lower carrying capacity for at least one salt in solution with the liquid composition. The liquid composition may be miscible with the solvent. The solvent may also have a lower boiling point than the liquid composition. The method further includes precipitating some of the salt out of the liquid and removing the precipitate. The solvent may then be separated, leaving the liquid composition with a reduced salt concentration. The solvent may be reused if recovered after separation. The apparatus includes elements for implementing the method.

REMOVAL OF DISSOLVED SALTS USING A SOLVENT

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

[0001] The present disclosure relates to a method and apparatus of removing dissolved salts from a liquid using a solvent, and, in particular, a method and apparatus of removing the dissolved salts from production water using an organic solvent.

2. Description of the Related Art

[0002] Hydraulic fracturing generally involves the fracturing of rock layers using pressurized liquid. A common liquid used in hydraulic fracturing is water. Various sediments, salts, and other impurities may be contained in the water after the fracturing is performed. Prior to release into the environment, the "frac water" may be processed to remove at least some of the impurities.

[0003] Generally, purification may be used to remove unwanted or harmful substances from water. Common purification techniques include reverse osmosis filtration and distillation. These techniques are often used for purification of drinking water. Both reverse osmosis and distillation require energy to separate the unwanted substances, such as excess salts and minerals, from the water. When large quantities of water (such as frac water) require some degree of impurity removal, reverse osmosis and distillation operations may be vecry energy, and thus cost, intensive. What is needed is a purification process that will remove select impurities from the water that does not have the substantial energy requirements of reverse osmosis and distillation.

BRIEF SUMMARY OF THE DISCLOSURE

[0004] In aspects, the present disclosure is related to removing dissolved salts from a liquid using a solvent, and, in particular, removing the dissolved salts from frac water using an organic solvent.

[0005] One embodiment according to the present disclosure includes a method of removing at least part of at least one dissolved salt from a liquid composition, the method comprising the steps of: combining a first quantity of the liquid composition and a quantity of a second solvent, the liquid composition comprising: a first solvent, and the at least one dissolved salt; precipitating the amount of the at least one dissolved salt out of the liquid composition, wherein the first solvent has a carrying capacity for the at least one dissolved salt that is greater than the carrying capacity of the second solvent for the at least one dissolved salt; removing the at least part of the at least one dissolved salt from contact with the first quantity of the liquid composition and second solvent; and separating the second solvent from the first quantity of the liquid composition. The separating step may comprise flashing the second solvent off of the first quantity. The method may also include one or more of: i) removing particulates from the first quantity, ii) destroying microorganisms in the first quantity, iii) removing a layer from the first quantity, and iv) recovering the separated second solvent. The recovered second solvent may be added to a second quantity of the liquid composition or added to another liquid composition comprising a third solvent and another at least one dissolved salt. The method may also include estimating a size of the second solvent quantity. The estimate of the size of the quantity of the second solvent may include using an algorithm based on the carrying capacity of the first solvent for the at least one dissolved salt and the carrying capacity of the second solvent for the at least one dissolved salt. The quantity of the second solvent may be based on a desired amount of that at least one dissolved salt remaining in the first quantity of the liquid composition after precipitation. The second solvent may comprise at least one organic solvent. The at least one organic solvent may be acetone and ethanol. The at least one organic solvent may comprise at least one alcohol. The at least one alcohol may be one or more of ethanol and methanol. The at least one dissolve salt may comprise at least one of sodium chloride and potassium chloride. The liquid composition may be frac water.

[0006] Another embodiment according to the present disclosure may include a method for removing a dissolved salt, the method comprising: combining a solvent with frac water, the frac water comprising water and the dissolved salt, wherein the solvent comprises at least one of: ethanol and methanol; precipitating at least part of the salt from the solution; removing the precipitate from contact with the frac water and the solvent; flashing off the solvent from the water and the unprecipitated salt; and recovering the flashed solvent.

[0007] Another embodiment according to the present disclosure may include a method of extracting a dissolved salt out of a quantity of a liquid composition, the method comprising the steps of: precipitating at least part of the dissolved salt out of the quantity of the liquid composition using a quantity of a second solvent with a lower carrying capacity than a carrying capacity of a first solvent in the liquid composition; removing the precipitated salt from contact with the liquid composition and the second solvent; separating the second solvent quantity from the quantity of the liquid composition; and recovering the second solvent quantity. The precipitating step may comprise combining the liquid composition and the second solvent. The separating step may comprise flashing the second solvent off of the first quantity. The method may include one or more of: i) adding the separated second solvent to a second quantity of the liquid composition, ii) adding the separated second solvent to another liquid composition comprising a third solvent and another at least one dissolved salt, iii) removing particulates from the first quantity, iv) destroying microorganisms in the first quantity, v) removing a layer from the first quantity, and vi) estimating a size of the second solvent quantity. The estimation of the size of the second solvent quantity may include using an algorithm based on the carrying capacity of the first solvent for the at least one dissolved salt and the carrying capacity of the second solvent for the at least one dissolved salt. The size of the quantity of the second solvent may be based on a desired amount of that at least one dissolved salt remaining in the first quantity of the liquid composition after precipitation.

[0008] Another embodiment according to the present disclosure includes an apparatus for removing dissolved salts from a liquid composition, the system comprising: a container configured to store a quantity of the liquid composition, the liquid composition comprising a first solvent and at least one dissolved salt; a controller configured to add a predetermined quantity of a second solvent to the container; a controller configured to estimate the predetermined quantity of the second solvent based on a selected output salt concentration; a salt removal means configured to remove a precipitated salt from the container; a heater in thermal communication with the second solvent and configured to separate the second solvent from the liquid composition after the precipitated salt has been removed; and a recovery container configured to store the separated second solvent. The controller may be configured to receive the selected output salt concentration. The predetermined quantity of the second solvent may be estimated by an algorithm based on the carrying capacity of the first solvent for the at least one dissolved salt and the carrying capacity of the second solvent for the at least one dissolved salt. The apparatus may also include one or more of: i) a filter configured to remove the particulate from the first quantity, ii) a biocide, and iii) a skimming means for removing a layer from the first quantity.

[0009] Another embodiment according to the present disclosure may include a method of reducing a salt concentration in a liquid composition, the method comprising: estimating a quantity of a second solvent required to be combined with a quantity of the liquid composition to reduce the salt concentration of the liquid composition to a selected level after the second solvent has been separated from the liquid composition. The method may also include estimating an amount of energy required to separate the second solvent from the liquid composition by flashing off the second solvent and combining the estimated quantity of the second solvent with the quantity of the liquid composition when the amount of energy is less than or equal to an amount of energy required for an alternative salt removal operation, such as distillation or reverse osmosis. The method may also include precipitating the amount of the at least one dissolved salt out of the liquid composition; removing the at least part of the at least one dissolved salt from contact with the first quantity and the second solvent; and separating the second solvent from the first quantity of the liquid composition. The method may also include one or more of: i) adding the separated second solvent to a second quantity of the liquid composition, ii) adding the separated second solvent to another liquid composition comprising a third solvent and another at least one dissolved salt, iii) removing a particulate from the first quantity, iv) destroying microorganisms in the first quantity, and v) removing a layer from the first quantity.

[0010] Another embodiment according to the present disclosure may include a non-transitory computer-readable medium product, the medium comprising instructions thereon that, when executed by a processor, perform a method, the method comprising: estimating a quantity of a second solvent required to be combined with a quantity of a liquid composition to reduce a salt concentration of the liquid composition to a selected level after the second solvent has been separated from the liquid composition. The method may also include estimating an amount of energy required to separate the second solvent from the liquid composition by flashing off the second solvent; and transmitting an instruction to combine the estimated quantity of the second solvent with the quantity of the liquid composition when the amount of energy is less than or equal to an amount of energy required for an alternative salt removal operation.

[0011] Examples of the more important features of the disclosure have been summarized rather broadly in order that the detailed description thereof that follows may be better understood and in order that the contributions they represent to the art may be appreciated. There are, of course, additional features of the disclosure that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] For a detailed understanding of the present disclosure, reference should be made to the following detailed description of the embodiments, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, wherein:

FIG. 1A is a diagram of a container holding a liquid composition with dissolved salts and a separately stored solvent according to one embodiment of the present disclosure;

FIG. 1B is a diagram of the container holding a mixed liquid composition of the liquid composition and stored solvent of **FIG. 1A** to one embodiment of the present disclosure;

FIG. 1C is a diagram of a container holding the mixed liquid composition of **FIG. 1B** as salts precipitate out of the mixed liquid composition according to one embodiment of the present disclosure;

FIG. 1D is a diagram of a container holding the mixed liquid composition of **FIG. 1C** after the precipitated salts have been removed according to one embodiment of the present disclosure;

FIG. 1E is a diagram of a container as the solvent is separated to leave behind the original liquid composition of **FIG. 1A** minus the precipitated salts according to one embodiment of the present disclosure;

FIG. 2 is a flow chart of a method of reducing a salt concentration of a liquid composition according to one embodiment of the present disclosure; and

FIG. 3 is a flow chart of another method of reducing salt concentration of a liquid composition according to one embodiment of the present disclosure.

FIG. 4 is diagram for an apparatus for reducing a salt concentration of a liquid composition according to one embodiment of the present disclosure;

FIG. 5 is a flow chart for performing an estimate of an amount of solvent to be added to a liquid composition to reduce a salt concentration of the liquid composition to a selected value according to one embodiment of the present disclosure;

FIG. 6 is a flow chart for performing an estimate of an amount of salt that will be precipitated when an amount of solvent is added to an amount of a liquid composition according to one embodiment of the present disclosure; and

FIG. 7 is a schematic of a computer system configured to implement the method of **FIG. 2** according to one embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0013] Generally, the present disclosure relates to removing dissolved salts from a liquid using a solvent, and, in particular, removing the dissolved salts from production water using an organic solvent. The present disclosure is susceptible to embodiments of different forms. They are shown in the drawings, and herein will be described in detail, specific embodiments of the present disclosure with the understanding that the present disclosure is to be considered an exemplification of the principles of the present disclosure and is not intended to limit the present disclosure to that illustrated and described herein.

[0014] At a specified temperature, two different solvents may have different carrying capacities or solubilities. For example, in pure water at 298.15 degrees Kelvin, the water may hold a mass fraction of 26.476 percent of potassium chloride in solution. Ethanol, at the same 298.15 degrees Kelvin may only hold a mass fraction of 0.034 percent of potassium chloride in solution. In some instances, combined solvents, such as water and ethanol, may have a lower combined carrying capacity than the individual contributions to carrying capacity by the solvents. A combination of 50 percent water and 50 percent ethanol by mass has a combined carrying capacity for potassium chloride of 6.198 percent, which is less than the carrying capacity of the separate water and ethanol (26.476%*50% + 0.034%*50% = 13.255%).

[0015] Combining pure ethanol with a solution of water saturated with potassium chloride may result in the precipitation of some of the salt out of the solution because the carrying capacity of the combined water and ethanol may be less than the salt that is dissolved in the water before combination. Since, the combined water and ethanol cannot retain the 13.238 percent mass fraction of potassium chloride (26.476*50% + 0*50%), but only 6.198 percent, the remaining potassium chloride will precipitate out of the solution. Salt that could not be easily removed while in solution may be removed as a solid once precipitated.

[0016] The solvents may be separated after salt removal, such that one solvent is removed and recovered for reuse and the other solvent retains the unprecipitated salts. The amount of salt removed may be a function of the amount of energy that the user desires to expend. For example, if the goal is to reduce the concentration of potassium chloride in water by adding a quantity of removable ethanol, then the amount of remaining potassium chloride will be a function of the carrying capacity of a solution of water and ethanol for potassium chloride and the amount of energy required to remove the ethanol from the solution.

[0017] In another example, one kilogram of pure water at 298.15 degrees Kelvin may include 300 grams of sodium chloride in solution. The maximum carrying capacity of one kilogram of pure water at 298.15 degrees Kelvin is 360 grams for sodium chloride, thus the water is not fully saturated. Under the same conditions, one kilogram of a combination of 80 percent acetone and 20 percent ethanol (80/20 solvent) may only have a carrying capacity of 0.130 grams for sodium chloride. The use of an 80/20 ratio of acetone to ethanol is illustrative and exemplary only, as other ratios to the two solvents may be used. A combination of 25 percent water and 75 percent 80/20 solvent has a combined carrying capacity for sodium chloride of about 22.4 grams per kilogram. Thus, the four kilograms of the solution could hold about 89.6 grams of sodium chloride. The remaining 210.4 grams of sodium chloride would precipitate out of the solution. Thus 70.1 percent of the original 300 grams of sodium chloride may be removed as precipitate, and after separations of the acetone and ethanol from the water (such as through flashing), the remaining sodium chloride-water solution will have 89.6 grams of sodium chloride in one kilogram of water, or 29.9 percent of the original 300 grams of sodium chloride in solution.

[0018] **FIG. 1A** shows a diagram of a first container **110** holding a quantity of a liquid composition **120** according to one embodiment of the present disclosure. The liquid composition **120** may comprise a first solvent and one or more dissolved salts. In some embodiments, the liquid composition **120** may be frac water. Also shown is a quantity of a second solvent **130**. The quantity of the second solvent **130** maybe selected based on the quantity of the liquid composition **120**, the concentration of dissolved salts in the liquid composition **120**, and a target concentration of dissolved salts in the first solvent. The target concentration of dissolved salts may be lower than the concentration of dissolved salts in the liquid composition **120**. The second solvent **130** may have a carrying capacity for the dissolved salts that is lower than the carrying capacity of the first solvent that is in the liquid composition **120**. The second solvent **130** may have a boiling point that is lower than the first solvent.

[0019] The second solvent **130** may include an inorganic solvent or an organic solvent. Suitable organic solvents may include, but are not limited to, one or more of: i) alcohol, ii) acetaldehyde, iii) acetonitrile, iv) dimethoxyethane, v) ethanol, vi) ethylamine, vii) methanol, viii) methyl isocyanide, ix) isopropyl alcohol, and x) tetrahydrofuan. Suitable inorganic solvents may include, but are not limited to, one or more of: i) dimethylhydrazine, ii) unsymmetrical dimethylhydrazine, iii) hydrofluoric acid, and iv) nitric acid. In some embodiments, the dissolved salts may include one or more of: i) sodium chloride and ii) potassium chloride. As would be understood by a person of ordinary skill in the art with the benefit of the present disclosure, some the substances that may serve as the second solvent may also be suitable as a first solvent in second combination, so long as the second solvent in the second combination i) has a lower boiling point than the boiling point of the first solvent, ii) has a lower carrying capacity for the salt than the carrying capacity for the salt of the first solvent, and iii) is miscible with the first solvent. For example, ethanol and acetone may both be used as the second solvent with water (first solvent), and acetone may also be used as a second solvent with ethanol (first solvent).

[0020] In some embodiments, the second solvent may include a combination of solvents, such as a mixture of acetone (dimethyl ketone) and ethanol. As discussed above, the combined solvent has a lower boiling point than the first solvent, a lower carrying capacity for the salt than the carrying capacity of the first solvent, and is miscible in the first solvent. In some embodiments, the combination may include two solvents that individually are not fully miscible in the first solvent but are fully miscible when the first solvent and the combined solvent are combined. In one exemplary embodiment, the second solvent may be a combined solvent of acetone and ethanol. In another embodiment, the combined solvent may be 80 percent acetone and 20 percent ethanol and the first solvent may be water.

[0021] The first container **110** may be any form of containment configured to hold the liquid composition **120** and will not chemically react with either the liquid composition **120** or the second solvent **130**. Generally, the first container **110** may be any suitable reactor vessel. Suitable reactor vessels may include, but is not limited to, i) a barrel, ii) a flask, iii) a pit, iv) a subterranean cavern, v) a tank, and vi) a borehole. The first container **110** may be sealed or open to the environment.

[0022] **FIG. 1B** shows a diagram of a second liquid composition **140** that is made up of the combination of the liquid composition **120** and the second solvent **130**. Due to the differences in the carrying capacities of the first solvent and the second solvent **130**, excess salt may precipitated out of solution.

[0023] **FIG. 1C** shows a diagram of a precipitated salt **150** that has separated from a liquid composition **160**. The liquid composition **160** may include the first solvent, the second solvent **130**, and the unprecipitated salts that have remained in solution.

[0024] **FIG. 1D** shows a diagram of the liquid composition **160** after the precipitated salts **150** have been removed from the first container **110**. The precipitated salts **150** may be removed by any means known to a person of ordinary skill in the art so long as the removal prevents the salts from reentering the liquid composition **160**, including, but not limited to, gravity driven draining, dredging, raking, and scooping.

[0025] **FIG. 1E** shows a diagram of the liquid composition **160** being separated. Here, the second solvent **130** is shown being removed through a heating process, such as flashing, where a heat source **180** boils off the second solvent **130**. The post-flashing remainder may be a liquid composition **170** that comprises the first solvent and the unprecipitated salts. The second solvent **130** may be collected by a collection device **190** for reuse or disposal.

[0026] **FIG. 2** shows an exemplary method **200** for reducing salt content of a solution according to one embodiment of the present disclosure. In step **210**, a target salt concentration of the liquid composition **120** may be selected. The target salt concentration is lower than the starting salt concentration of the liquid composition **120**. In step **220**, a quantity of a second solvent **130** is estimated for addition to a quantity of the liquid composition **120**. The estimation may include using an algorithm based on the carrying capacities of the first solvent and the second solvent **130**. The estimation may also be based on the quantity of dissolved salts in the first composition **120** (starting salt concentration). The estimation may be based on the type of salt or salts that are dissolved in the liquid composition **120**. In some embodiments, steps **210** and **220** may be optional. In some embodiments, the algorithm may include an estimate of the amount of energy required to perform the method **200**. In some embodiments, the algorithm may include a comparison between the estimated amount of energy and the energy requirements of alternatives to method **200** for reducing a dissolved salt concentration, such as reverse osmosis and distillation.

[0027] In step **230**, the first composition **120** and the second solvent **130** may be combined to form a mixed liquid composition **140**. The mixed liquid composition **140** may be formed when the second solvent **130** may be added to the liquid composition **120**; the liquid composition **120** may be added to the second solvent **130**; or the second solvent **130** and the liquid composition **130** may be mixed simultaneously in a separate container. In step **240**, at least part of the dissolved salts may precipitated out of the mixed liquid composition **140** to form a precipitate **150** and a remaining mixed liquid composition **160**. In step **250**, the precipitate **150** may be removed from the first container **110**. In step **260**, the second solvent **130** may be removed from the remaining mixed liquid composition **160**. The separation step may be performed by flashing off the second solvent **130** from the remaining mixed liquid composition **160**. Flashing is may be performed by applying heat to the remaining mixed liquid composition **160** until the second solvent **130** boils off. In some embodiments, the flashing of the second solvent **130** may be performed at ambient temperatures (additional heat source not required). As would be understood by one of ordinary skill in the art, the second solvent **130** may have a lower evaporation temperature than then first solvent, such that the unprecipitated salts remain dissolved in the first solvent. After the second solvent **130** is removed, the remaining liquid composition **170** may include the first solvent and the unprecipitated salts in solution. The use of a flashing technique to separate the second solvent **130** from the remaining liquid composition **170** is illustrative and exemplary only, as other separation techniques known to persons of ordinary skill in the art with the benefit of the present disclosure may be used. In some embodiments, the type of heat source **180** and/or the amount of heat used in the separation process may be selected based on the amount of energy required for dissolved salt removal or water purification alternatives.

[0028] In step **270**, the second solvent **130** may be recovered from the separation process. In step **280**, the recovered second solvent **130** may be reused. In some embodiments, the reuse may include mixing with a second quantity of the liquid composition **120** to reduce salt concentration or with in another liquid composition. In some embodiments, steps **270** and **280** are optional. The precipitated salts **150** from step **250** may also be used, such that the method **200** may also be used as an extraction process for removing salts from a solution.

[0029] **FIG. 3** shows a flow chart of another exemplary method **300** for reducing salt content of a liquid according to the present disclosure. Here, the liquid may also include, in addition to liquid composition **120**, impurities other than dissolved salts, such as a non-miscible second composition in mixture, microorganisms, and particulates. The particulates may include undissolved substances that are soluble or have the potential to be soluble in the first solvent and/or substances that do not dissolve into solution with the first solvent.

[0030] In step **310**, the mixture of the first liquid composition **120** and the second liquid composition may be separated. Being non-miscible, the first composition **120** and second composition may separate due to differences in density. In step **320**, the separated second composition may be removed from contact with the first composition **120**. The removal may be performed by skimming the second composition off of the first composition **120** (if the second composition is less dense than the first composition **120**). The use of skimming as a removal technique is exemplary and illustrative only, as other separation techniques known to persons of ordinary skill in the art with the benefit of the present disclosure may be used as well. In step **330**, the amount of particulates in the first composition **120** may be reduced. The reduction of particulates may be performed by filtering the first composition **120** or other suitable techniques known to persons of ordinary skill in the art.

[0031] In step **340**, microorganisms present in the first composition **120** may be destroyed. The destruction of the microorganisms may be performed by adding a biocide. The use of a biocide is exemplary and illustrative only, as other techniques, such as, but not limited to, exposing the first composition **120** to lethal radiation, may be used. Steps **230** through **280** from method **200** may be performed as a part of method **300**. Any of steps **310** through **340** may be optional. Steps **310** and **320**, step **330**, and step **340** may be performed in any order, including after and during steps **230** through **280**. In some embodiments, the destruction of microorganisms in step **340** may be performed by the addition of the second solvent **130** in step **230**, if the second solvent **130** is selected to have biocidal properties. In some embodiments, the biocide in step **340** and the second solvent **130** may be selected to destroy different types of microorganisms.

[0032] **FIG. 4** shows a diagram of an exemplary apparatus **400** for removing salt from the liquid composition **120**. The apparatus **400** may include a container **410** configured to hold a mixture of the second solvent **130** and the liquid composition **120**. The second solvent **130** may be stored in a storage vessel **420** and conveyed through the pipe **430** to the container **410**. A controller **433** may regulate the amount of solvent **130** that is conveyed into container **410**. A controller **435** may estimate the amount of solvent **130** that is to be conveyed into the container **410** and transmit the estimate to the controller **433**. The controller **435** may estimate the amount of solvent to be added and/or an amount of precipitated salt **150** to be removed by, using an equation, executing an algorithm (see **FIG. 5** and **FIG. 6**), or using a table. The controller **433** and the controller **435** may share an information processor or have separate information processors. As shown, the salt has precipitated from the mixture **140**. The salt precipitate **150** may collect at the bottom of the container **410** as the mixture **140** separates into the precipitate **150** and the mixture **160** comprising the first solvent, the unprecipitated salt, and the second solvent **130**. The precipitate **150** may be removed from the container **410** through a pipe **450**.

The use of gravity driven removal of the precipitate **150** from a container **410** is exemplary and illustrative only, as other removal techniques may be used alternatively or in addition to gravity driven removal, such as, but not limited to, dredging and raking.

[0033] The removal process may include some of the mixture **160**, so the mixture **160** and the precipitate **150** may be separated. The salt precipitate **150** is removed via the pipe **460**, while the mixture **160** is recirculated into the container **410** via the pipe loop **470**. If some of the mixture **160** is conveyed in the pipe **460**, then additional recovery techniques, as would be understood by a person of ordinary skill in the art would understand with the benefit of the present disclosure, may be used to recapture the mixture **160**. The pipe loop **470** may include a pump **473** to propel the mixture **160** and an optional heat exchanger **475**. The heat exchanger **475** may be configured to add sufficient heat to the mixture **160** to boil the second solvent **130**. In some embodiments, ambient temperatures may be sufficient for boiling off the second solvent **130** from the mixture **160** for recovery. A recovery pipe **440** may be disposed to capture the second solvent **130** when the second solvent **130** boils off from the mixture **160**. The recovery pipe **440** may convey the second solvent **130** to the storage tank **420**. A heat exchanger **445** may be disposed along the path from the recovery pipe **440** to the storage vessel **420** to recover heat energy from the second solvent **130**. As shown storage vessel **420** may be part of the second solvent **130** supply and recovery aspects, however, in some embodiments, storage second solvent **130** prior to use and after recovery may be in two or more separate vessels.

[0034] **FIG. 5** shows a flow chart of a method **500** for estimating a quantity of the second solvent **130** required to reduce the salt concentration of the liquid composition **120** to a selected level according to one embodiment of the present disclosure. In step **510**, a target salt concentration for the remaining liquid composition **170** (first composition **120** after removal of the precipitated salt **150**) may be received. In step **520**, a temperature of the first composition **120** may be received. In step **530**, a ratio of an amount of the second solvent **130** to be added to an amount of the first composition **120** in order to obtain the target salt concentration in the remaining liquid composition **170** may be estimated using the target salt concentration and the temperature of the first composition **120**. The estimation may be performed using at least one of: i) an equation, ii) an algorithm, and iii) a table. In step **540**, an amount of the first composition **120** may be received. In step **550**, an amount of the second solvent **130** needed may be estimated based on the ratio from step **530** and the amount of the first composition **120** from step **540**. In step **560**, an amount of energy required to boil off the amount of the second solvent **130** may be estimated based on the composition and amount of the second solvent **130**. In step **570**, an instruction to combine the liquid composition **120** and the second solvent **130** if the estimated amount of energy is below a threshold level. The threshold level may be based on the energy requirements of alternative salt removal operations, such as distillation and reverse osmosis. In some embodiments, the instruction to combine may be sent to the controller **433**. In some embodiments, steps **560** and **570** may be optional. In some embodiments, step **540** may be performed before step **530**. Steps **510**, **520**, and **540** may be performed in any order.

[0035] **FIG. 6** shows a flow chart of a method **600** for estimating a quantity of salt precipitated when an amount of the second solvent **130** is added to the liquid composition **120** according to one embodiment of the present disclosure. In step **610**, an amount of the first composition **120** may be received. In step **620**, a temperature of the first composition **120** may be received. In step **630**, an amount of the second solvent **130** may be received. In step **640**, the carrying capacity of the combined amounts of the first composition **120** and the second solvent **130** may be estimated. The estimation may be performed using at least one of: i) an equation, ii) an algorithm, and iii) a table. In step **650**, a salt concentration of the first composition **120** may be received. In step **660**, the quantity of precipitated salt **150** may be estimated. The estimation of the quantity of salt precipitated **150** may be based on i) the carrying capacity of the combined mixture of the first composition **120**, ii) the second solvent **130** and the salt concentration of the first composition **120**, and iii) the combined amounts of the first composition **120** and the second solvent **130**. In some embodiments, step **650** may be performed before step **640**. Steps **610**, **620**, **630**, and **650** may be performed in any order.

[0036] **FIG. 7** shows a schematic of an exemplary hardware environment **700** where the method may be implemented according to the present disclosure. The hardware environment may include an information processor **710**, a non-transitory computer-readable medium **720**, an input device **730**, a processor memory **740**, and may include peripheral information storage medium **750**. The hardware environment **700** may be located in a single location or distributed across multiple locations. The input device **730** may be any information reader or user input device, such as data card reader, keyboard, USB port, etc. The non-transitory computer-readable medium **720** may be any standard non-transitory computer information storage device, such as a ROM, USB drive, memory stick, hard disk, removable RAM, EPROMs, EAROMs, EEPROM, flash memories, and optical disks or other commonly used memory storage system known to one of ordinary skill in the art including Internet based storage. The non-transitory computer-readable medium **720** stores a program that when executed causes information processor **710** to execute the disclosed method, such as exemplary methods **200** and **300**. The non-transitory computer-readable medium **720** may also store suitability data about the first party and/or suitability data about the plurality of insurance products. In some embodiments, the suitability data about the first party and/or the suitability data about the plurality of insurance products may be stored in a peripheral information storage medium **750**, which may be any standard computer information storage device, such as a USB drive, memory stick, hard disk, removable RAM, or other commonly used memory storage system known to one of ordinary skill in the art including Internet based storage. The information processor **710** may be any form of computer or mathematical processing hardware, including Internet based hardware. When the program is loaded from the non-transitory computer-readable medium **720** into processor memory **740** (e.g. computer RAM), the program, when executed, causes information processor **710** to retrieve the suitability data from either the non-transitory computer-readable medium **720** or the peripheral information storage medium **750** and to process the information to perform the suitability analysis and/or provide the insurance product to the first party.

[0037] While the disclosure has been described with reference to exemplary embodiments, it will be understood that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the disclosure. In addition, many modifications will be appreciated to adapt a particular instrument, situation or material to the teachings of the disclosure without departing from the essential scope thereof. Therefore, it is intended that the disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this disclosure, but that the disclosure will include all embodiments falling within the scope of the appended claims.

CLAIMS

What is claimed is:

1. A method of removing at least part of at least one dissolved salt from a liquid composition, the method comprising the steps of:

combining a first quantity of the liquid composition and a quantity of a second solvent, the liquid composition comprising:

a first solvent, and

the at least one dissolved salt;

precipitating an amount of the at least one dissolved salt out of the liquid composition, wherein the first solvent has a carrying capacity for the at least one dissolved salt that is greater than the carrying capacity of the second solvent for the at least one dissolved salt;

removing the at least part of the at least one dissolved salt from contact with the first quantity of the liquid composition and second solvent; and

separating the second solvent from the first quantity of the liquid composition.

2. The method of claim 1, wherein the separating step comprises:

flashing the second solvent off of the first quantity.

3. The method of claim 1, further comprising:

recovering the separated second solvent.

4. The method of claim 3, further comprising:

adding the separated second solvent to a second quantity of the liquid composition.

5. The method of claim 3, further comprising:

adding the separated second solvent to another liquid composition comprising a third solvent and another at least one dissolved salt.

6. The method of claim 1, further comprising:

estimating a size of the second solvent quantity, wherein the size of the second solvent quantity is estimated by an algorithm based on the carrying capacity of the first solvent for the at least one dissolved salt and the carrying capacity of the second solvent for the at least one dissolved salt.

7. The method of claim 1, wherein a size of the quantity of the second solvent is based on a desired amount of that at least one dissolved salt remaining in the first quantity of the liquid composition after precipitation.

8. The method of claim 1, wherein the liquid composition further comprises a particulate; and the method further comprises:

removing the particulate from the first quantity.

9. The method of claim 1, wherein the liquid composition further comprises a microorganism; and the method further comprises:

destroying the microorganism in the first quantity.

10. The method of claim 1, wherein the liquid composition further comprises a first layer and a second layer; and the method further comprises:

removing the second layer from the first quantity.

11. The method of claim 1, wherein the second solvent comprises at least one organic solvent.

12. The method of claim 11, wherein the at least one organic solvent comprises acetone and ethanol.

13. The method of claim 11, wherein the at least one organic solvent comprises at least one alcohol.

14. The method of claim 13, wherein the at least one alcohol comprises at least one of: ethanol and methanol.

15. The method of claim 1, wherein the at least one dissolved salt comprises at least one of: sodium chloride and potassium chloride.

16. The method of claim 1, wherein the liquid composition is frac water.

17. An apparatus for removing dissolved salts from a liquid composition, the system comprising:

a container configured to store a quantity of the liquid composition, the liquid composition comprising a first solvent and at least one dissolved salt;

a controller configured to add a predetermined quantity of a second solvent to the container;

a controller configured to estimate the predetermined quantity of the second solvent based on a selected output salt concentration;

a salt removal means configured to remove a precipitated salt from the container;

a heater in thermal communication with the second solvent and configured to separate the second solvent from the liquid composition after the precipitated salt has been removed; and

a recovery container configured to store the separated second solvent.

18. The apparatus of claim 17, wherein the controller is configured to receive the selected output salt concentration.

19. The apparatus of claim 17, wherein the predetermined quantity of the second solvent is estimated by an algorithm based on the carrying capacity of the first solvent for the at least one dissolved salt and the carrying capacity of the second solvent for the at least one dissolved salt.

20. The apparatus of claim 17, wherein the liquid composition further comprises a particulate; and the apparatus further comprises:

a filter configured to remove the particulate from the first quantity.

21. The apparatus of claim 17, wherein the liquid composition further comprises a microorganism; and the apparatus further comprises:

a biocide.

22. The apparatus of claim 17, wherein the liquid composition further comprises a first layer and a second layer; and the apparatus further comprises:

a skimming means for removing the second layer from the first quantity.

23. The apparatus of claim 17, wherein the second solvent comprises at least one organic solvent.

24. The apparatus of claim 23, wherein the at least one organic solvent comprises at least one alcohol.

25. The apparatus of claim 24, wherein the at least one alcohol comprises at least one of: ethanol and methanol.

26. The apparatus of claim 17, wherein the at least one dissolved salt comprises at least one of: sodium chloride and potassium chloride.

27. The apparatus of claim 17, wherein the liquid composition is frac water.

28. A method of reducing a salt concentration in a liquid composition, the method comprising:

estimating a quantity of a second solvent required to be combined with a quantity of the liquid composition to reduce the salt concentration of the liquid composition to a selected level after the second solvent has been separated from the liquid composition.

29. The method of claim 28, wherein the liquid composition comprises a first solvent and a salt, and wherein the estimation is based on the carrying capacity for the salt of the first solvent and the carrying capacity for the salt of the second solvent.

30. The method of claim 28, further comprising:

estimating an amount of energy required to separate the second solvent from the liquid composition by flashing off the second solvent;

combining the estimated quantity of the second solvent with the quantity of the liquid composition when the amount of energy is less than or equal to an amount of energy required for an alternative salt removal operation;

precipitating the amount of the at least one dissolved salt out of the liquid composition;

removing the at least part of the at least one dissolved salt from contact with the first quantity and the second solvent; and

separating the second solvent from the first quantity of the liquid composition.

31. The method of claim 28, wherein the alternative salt removal operation is one of: distillation and reverse osmosis.

32. A non-transitory computer-readable medium product, the medium comprising instructions thereon that, when executed by a processor, perform a method, the method comprising:

estimating a quantity of a second solvent required to be combined with a quantity of a liquid composition to reduce a salt concentration of the liquid composition to a selected level after the second solvent has been separated from the liquid composition.

33. The non-transitory computer-readable medium product of claim 32, wherein the liquid composition comprises a first solvent and a salt, and wherein the estimation is based on the carrying capacity for the salt of the first solvent and the carrying capacity for the salt of the second solvent.

34. The non-transitory computer-readable medium product of claim 32, further comprising:

storing the selected level.

35. The non-transitory computer-readable medium product of claim 32, further comprising:

estimating an amount of energy required to separate the second solvent from the liquid composition by flashing off the second solvent; and

transmitting an instruction to combine the estimated quantity of the second solvent with the quantity of the liquid composition when the amount of energy is less than or equal to an amount of energy required for an alternative salt removal operation.

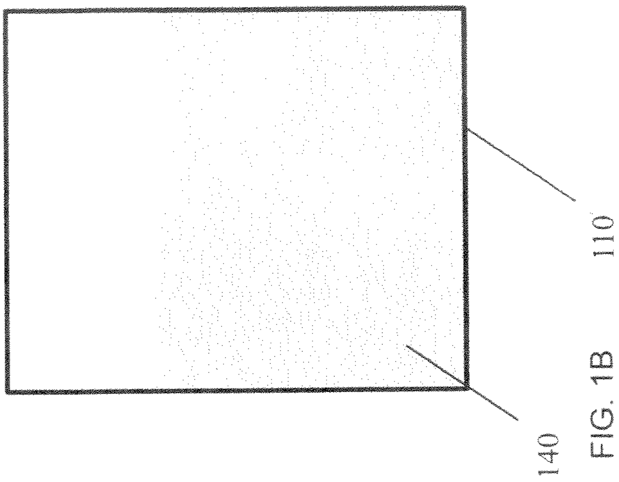

FIG. 1B

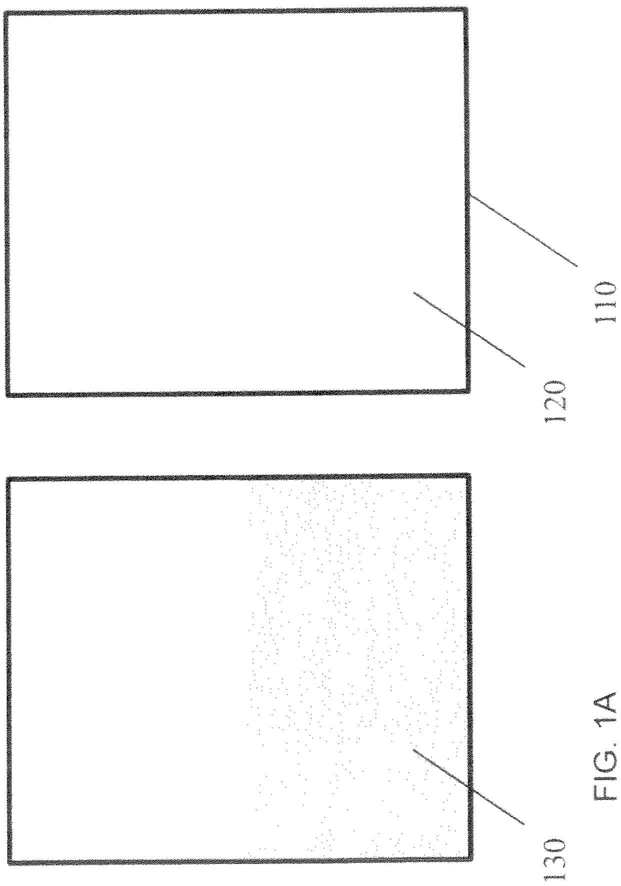

FIG. 1A

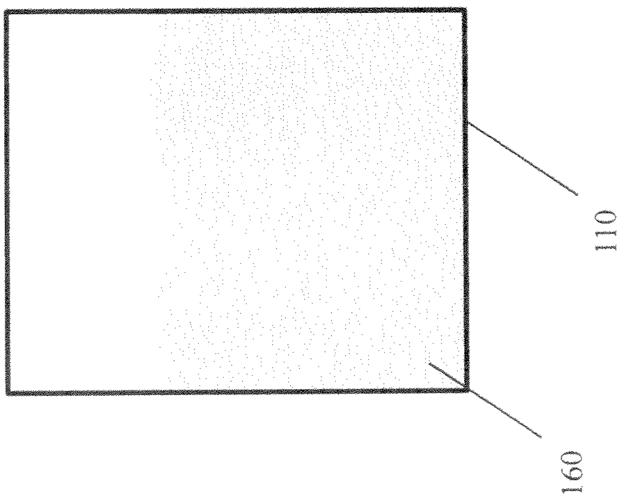

FIG. 1D

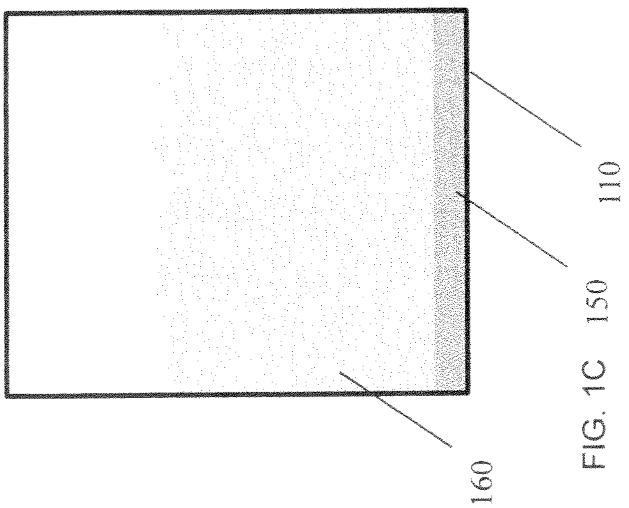

FIG. 1C

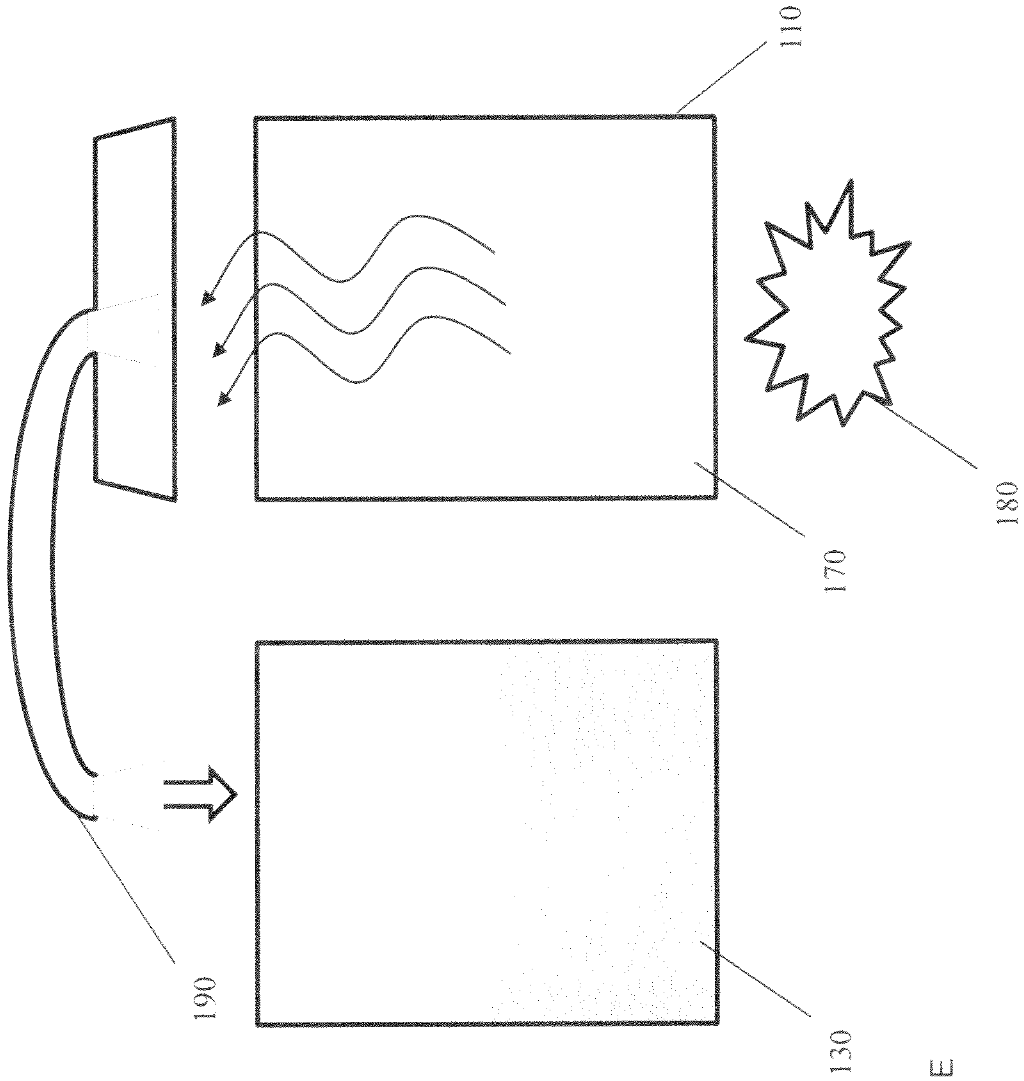

FIG. 1E

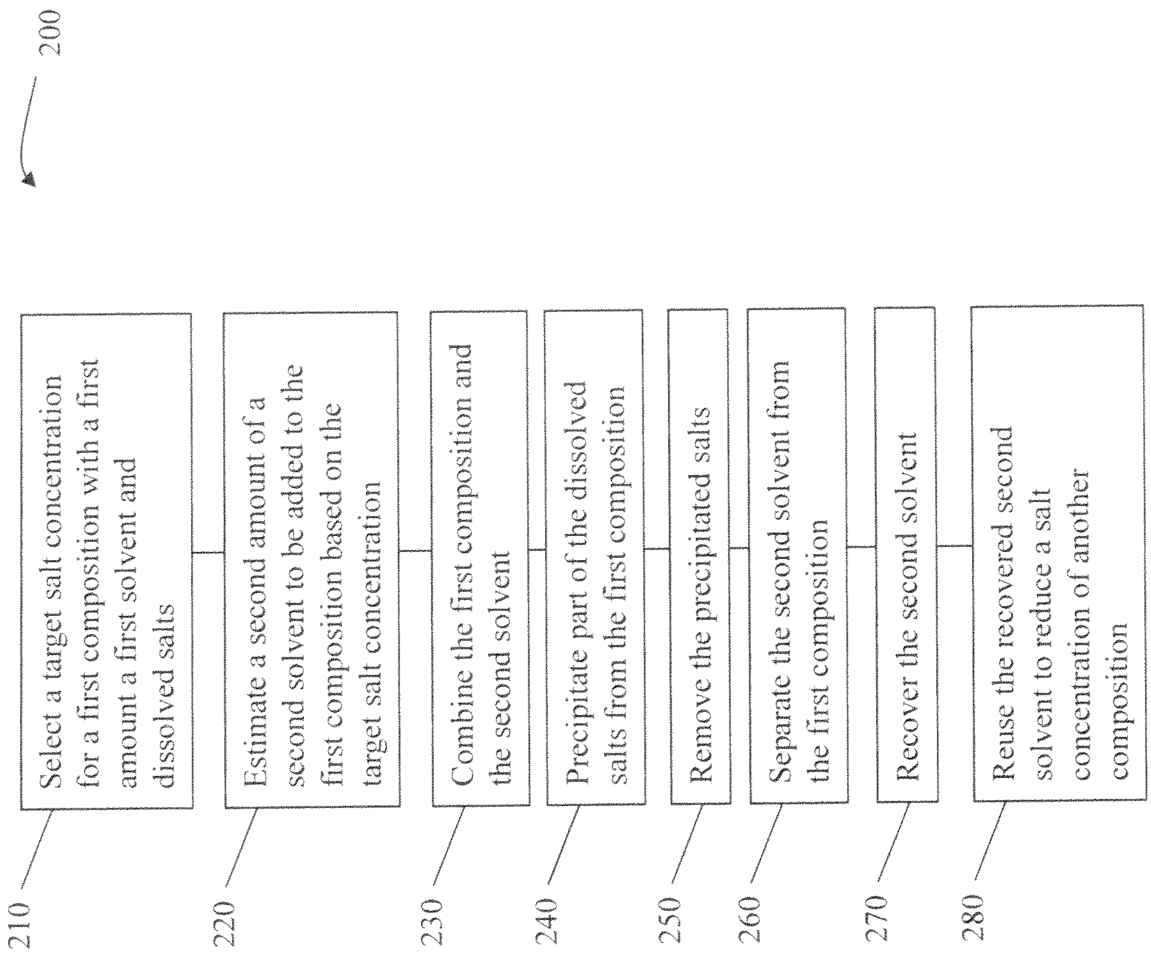
200
210
Select a target salt concentration for a first composition with a first amount a first solvent and dissolved salts
220
Estimate a second amount of a second solvent to be added to the first composition based on the target salt concentration
230
Combine the first composition and the second solvent
240
Precipitate part of the dissolved salts from the first composition
250
Remove the precipitated salts
260
Separate the second solvent from the first composition
270
Recover the second solvent
280
Reuse the recovered second solvent to reduce a salt concentration of another composition

FIG. 2

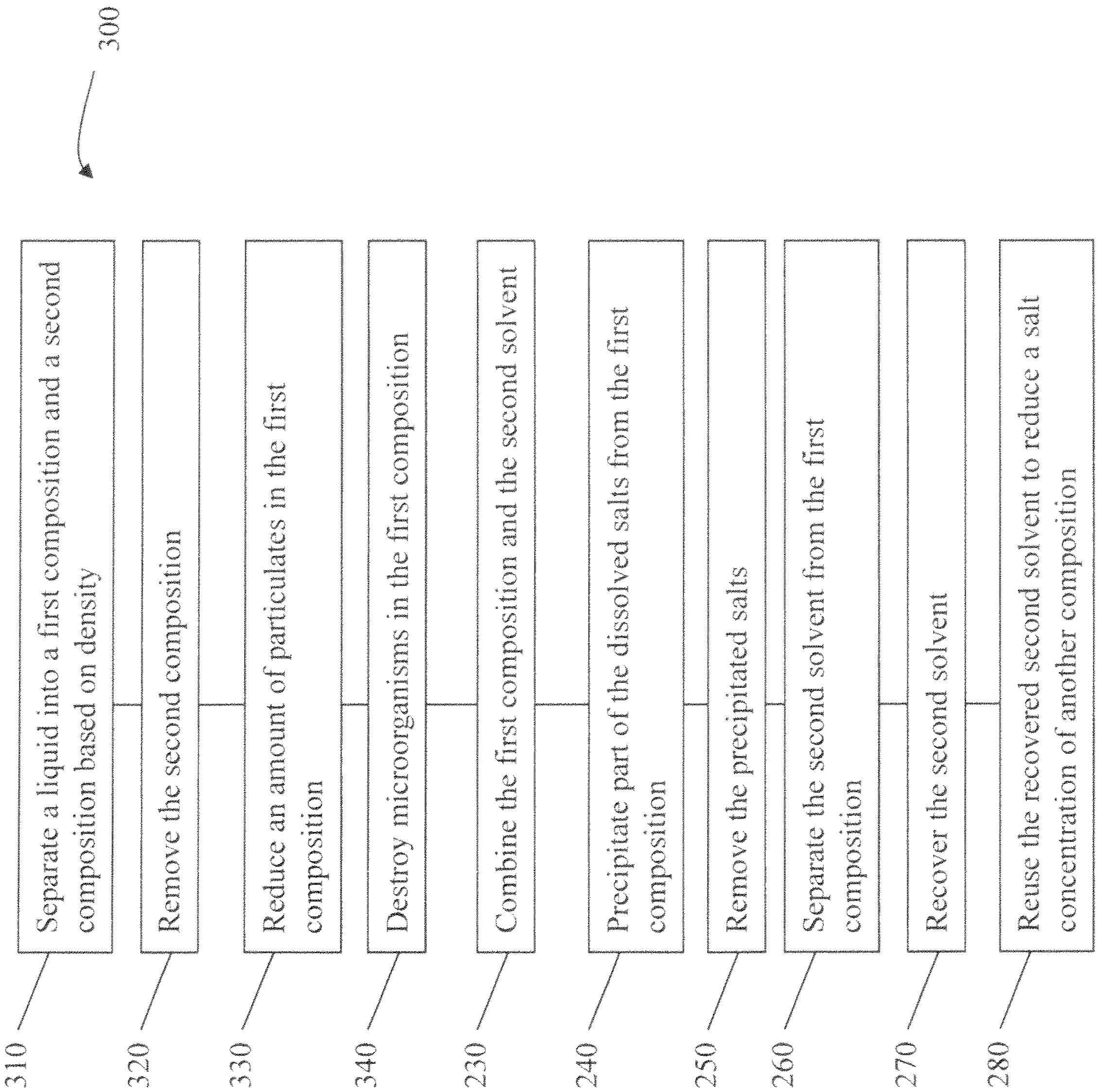
300
310 Separate a liquid into a first composition and a second composition based on density
320 Remove the second composition
330 Reduce an amount of particulates in the first composition
340 Destroy microorganisms in the first composition
230 Combine the first composition and the second solvent
240 Precipitate part of the dissolved salts from the first composition
250 Remove the precipitated salts
260 Separate the second solvent from the first composition
270 Recover the second solvent
280 Reuse the recovered second solvent to reduce a salt concentration of another composition

FIG. 3

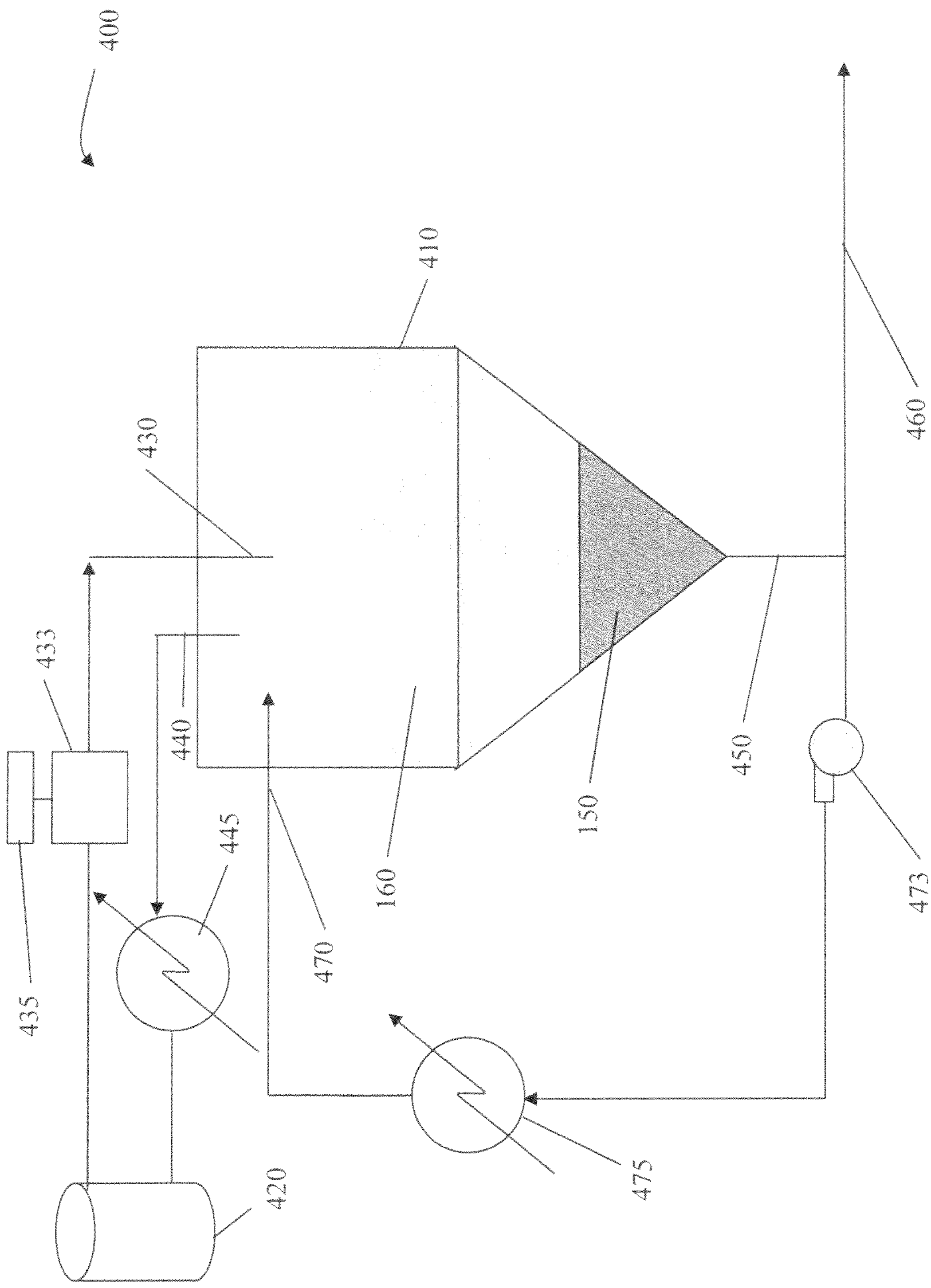

FIG. 4

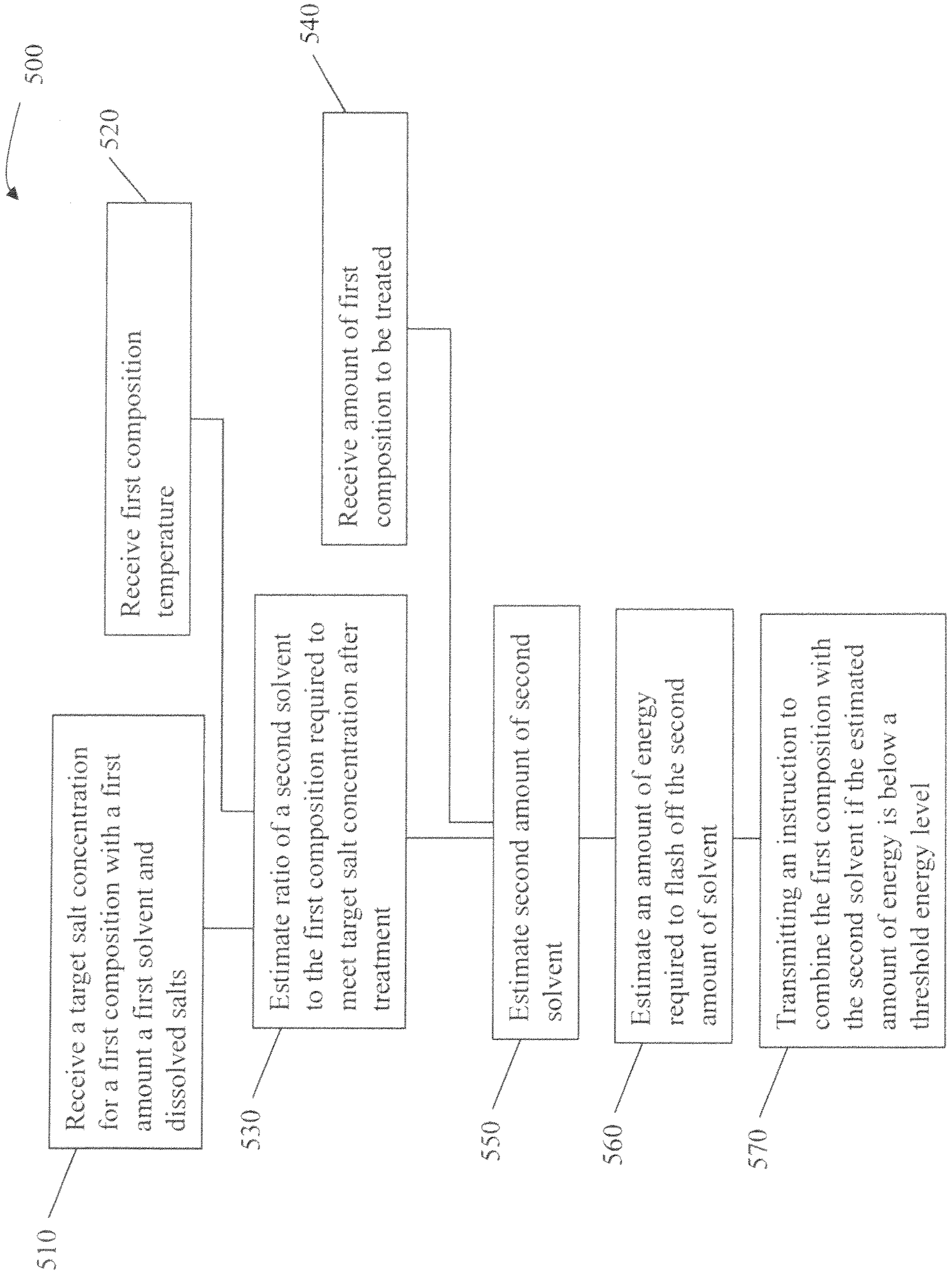
500
Receive a target salt concentration for a first composition with a first amount a first solvent and dissolved salts
510
Receive first composition temperature
520
Estimate ratio of a second solvent to the first composition required to meet target salt concentration after treatment
530
Receive amount of first composition to be treated
540
Estimate second amount of second solvent
550
Estimate an amount of energy required to flash off the second amount of solvent
560
Transmitting an instruction to combine the first composition with the second solvent if the estimated amount of energy is below a threshold energy level
570

FIG. 5

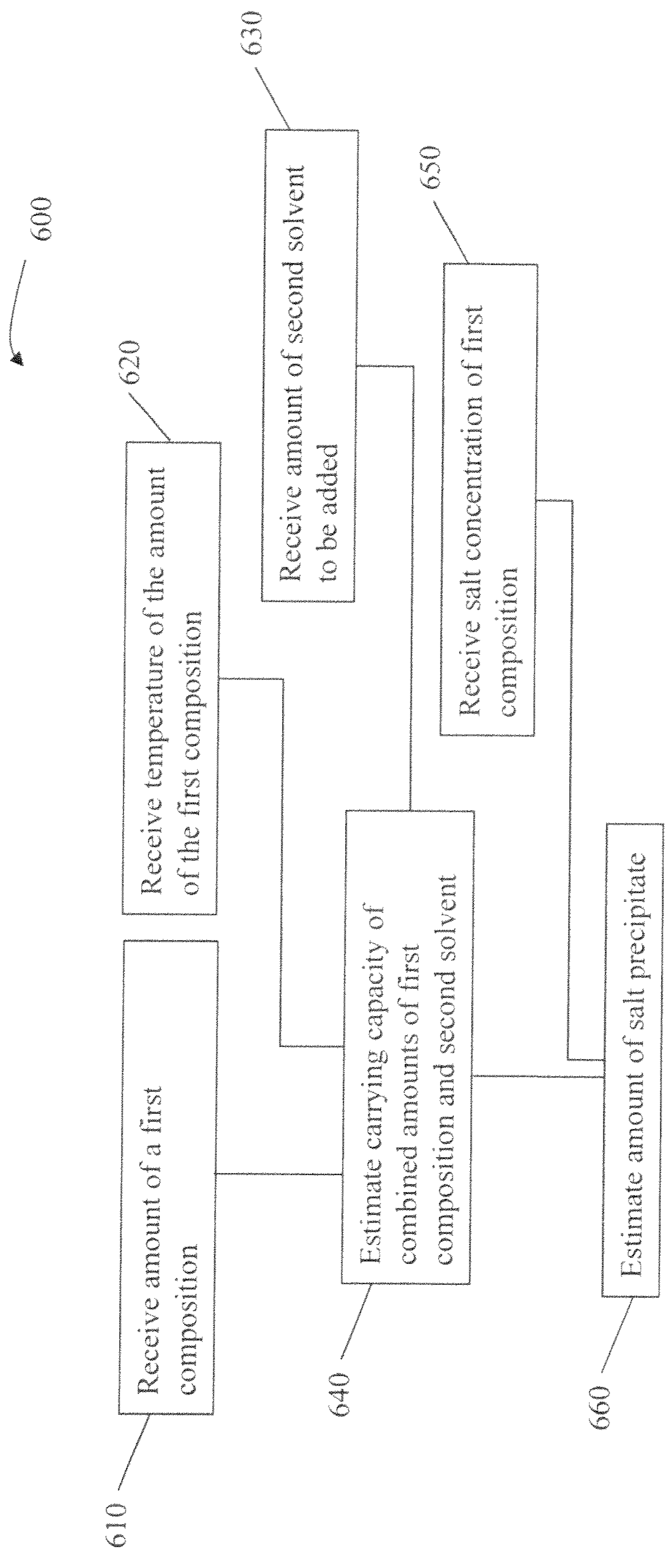
600
Receive amount of a first composition
610
Receive temperature of the amount of the first composition
620
Receive amount of second solvent to be added
630
Estimate carrying capacity of combined amounts of first composition and second solvent
640
Receive salt concentration of first composition
650
Estimate amount of salt precipitate
660

FIG. 6

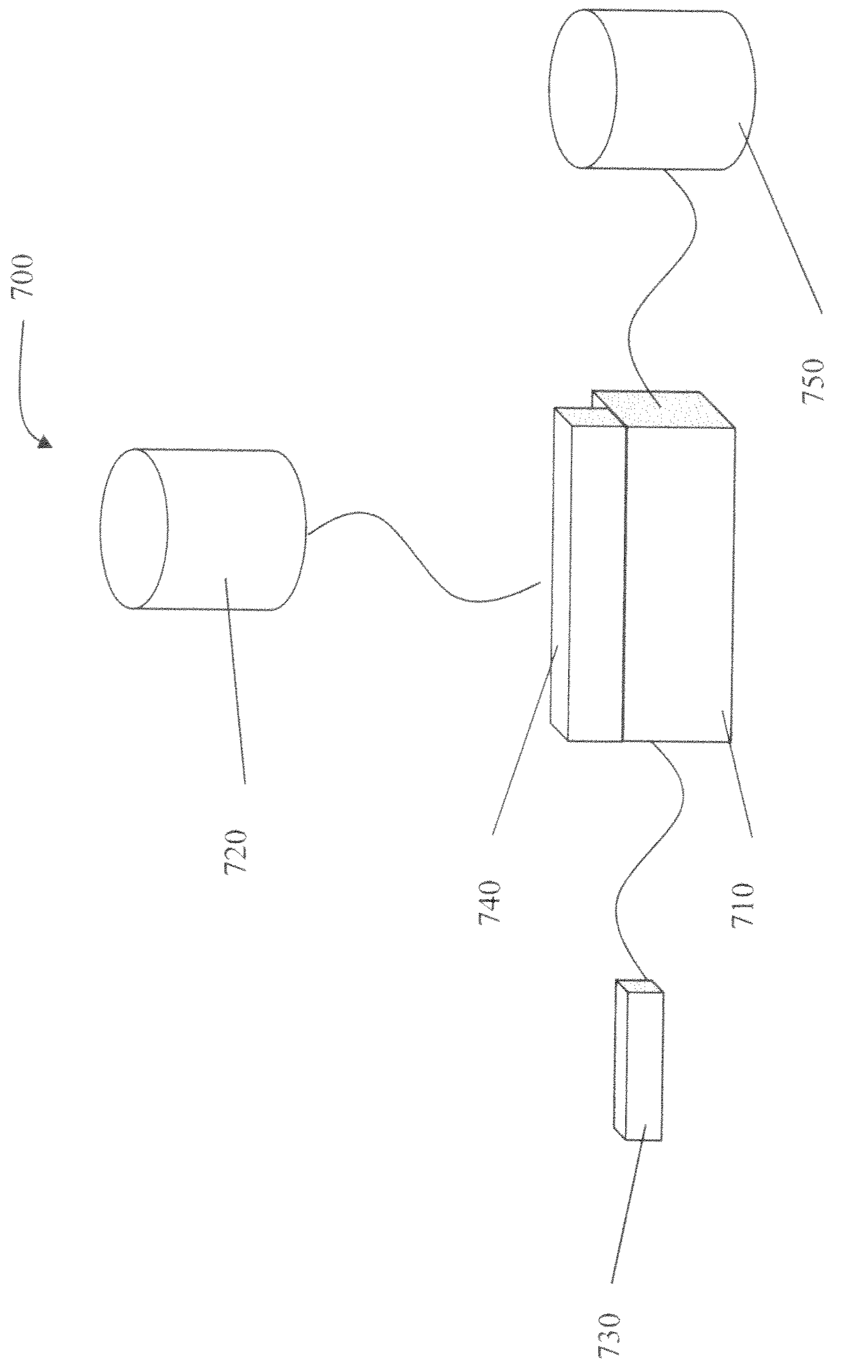

FIG. 7