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(54) **SYSTEMS AND METHODS FOR ENHANCED RECOVERY OF HYDROCARBONACEOUS FLUIDS**

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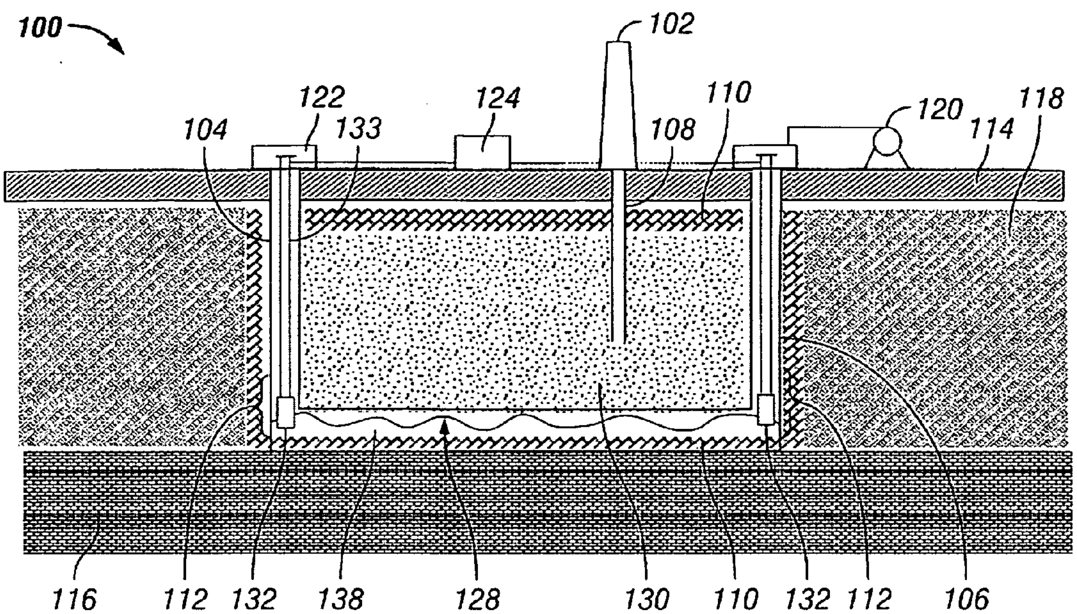
(57) **ABSTRACT**

A method for enhanced recovery of hydrocarbonaceous fluids, the method including the steps of connecting each of a plurality of wellbores together in fluid communication with a machined flow path, providing a surface fluid to the flow path, and generating an electrical field within the flow path to cause an electrochemical reaction to produce a gas from the fluid, such that the gas mixes with hydrocarbonaceous fluids and increases pressure within at least one of the plurality of wellbores, the flow path, and combinations thereof, thereby enhancing recovery of the hydrocarbonaceous fluid.



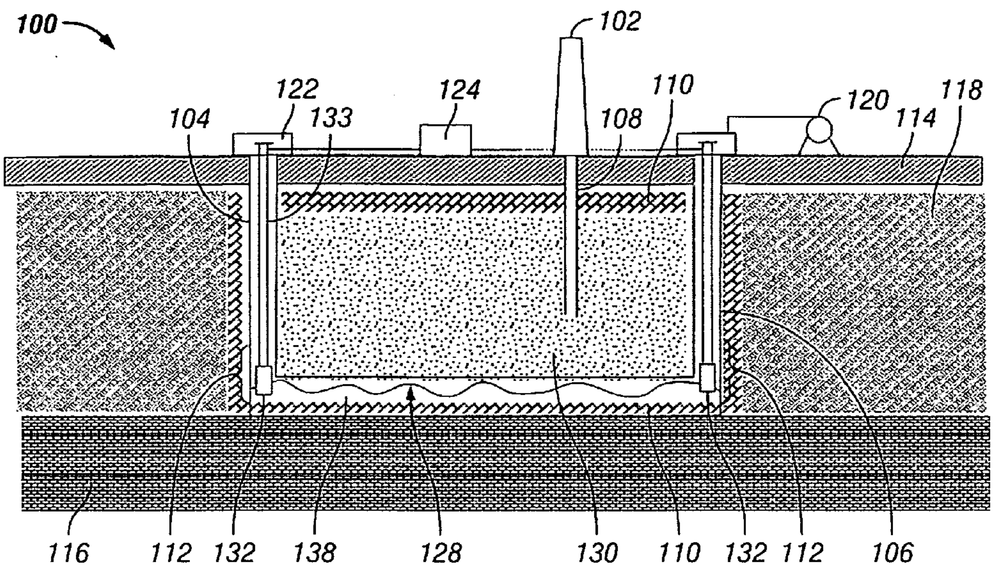


FIG. 1A

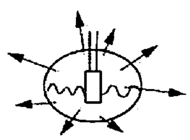


FIG. 1C

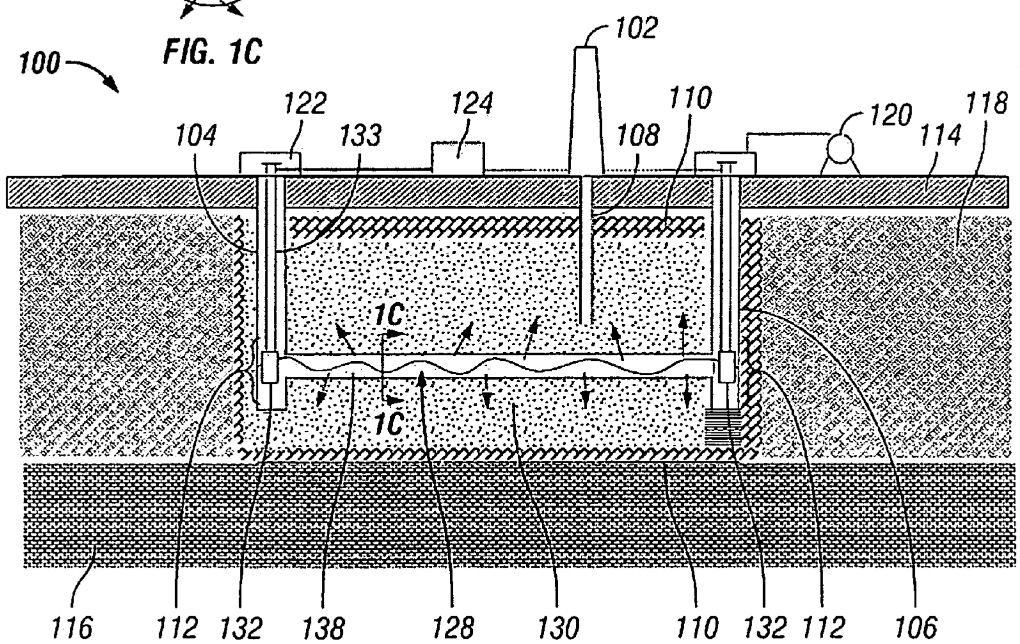
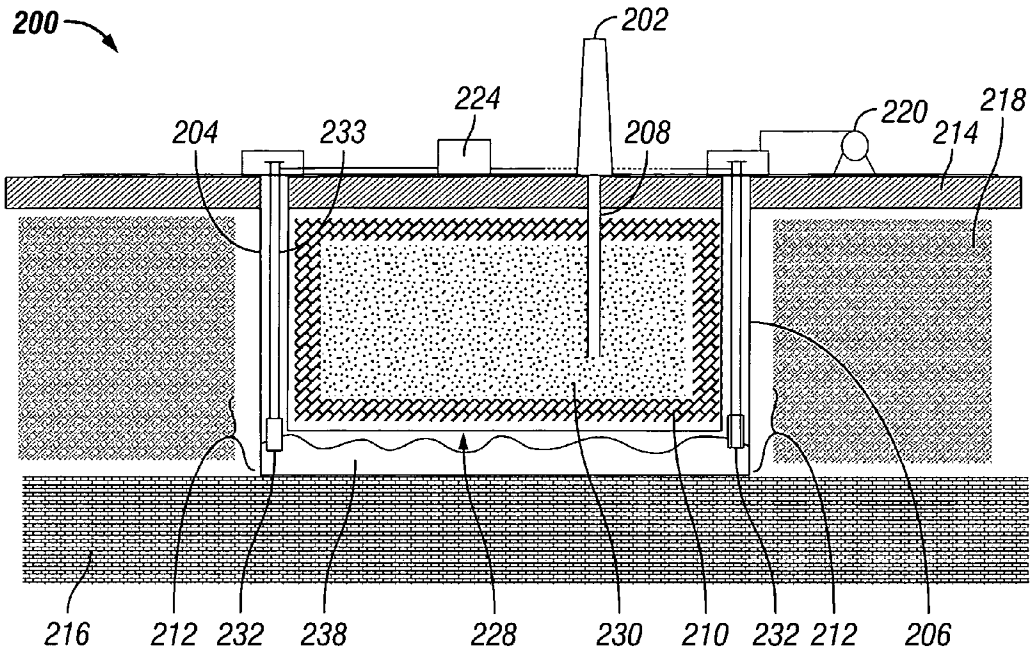


FIG. 1B


200
202
224
204
233
208
220
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214
216
212
232
238
228
230
210
232
212
206

FIG. 2

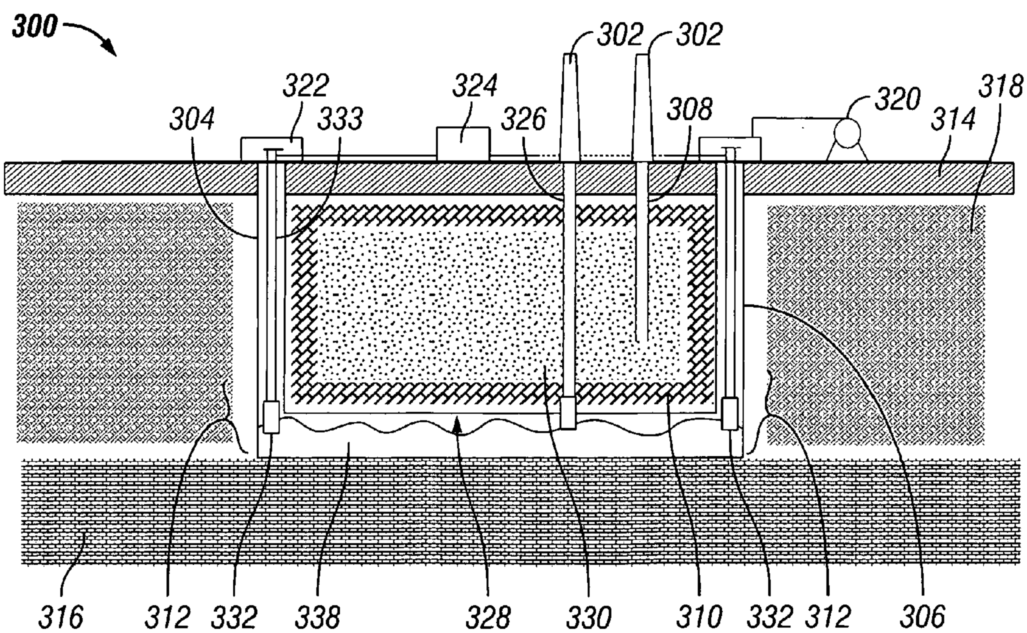
300
302
302
322
324
304
333
326
308
320
318
314
316
312
332
338
328
330
310
332
312
306

FIG. 3

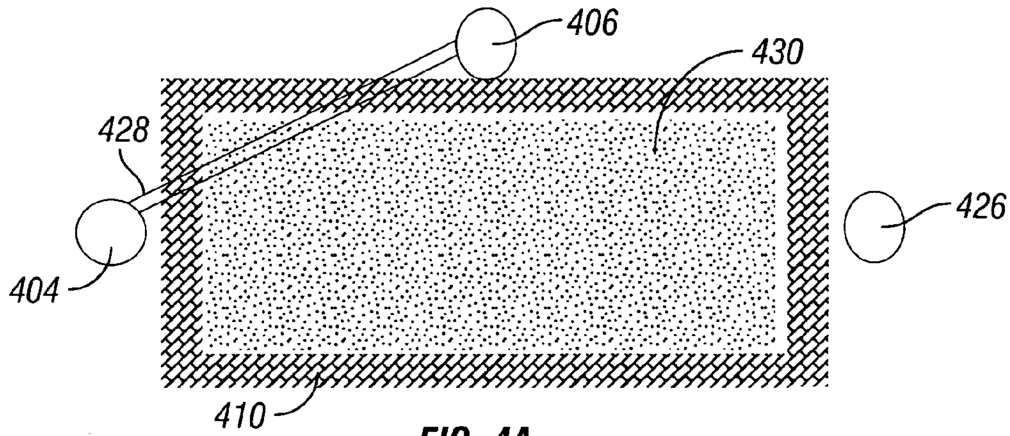

FIG. 4A

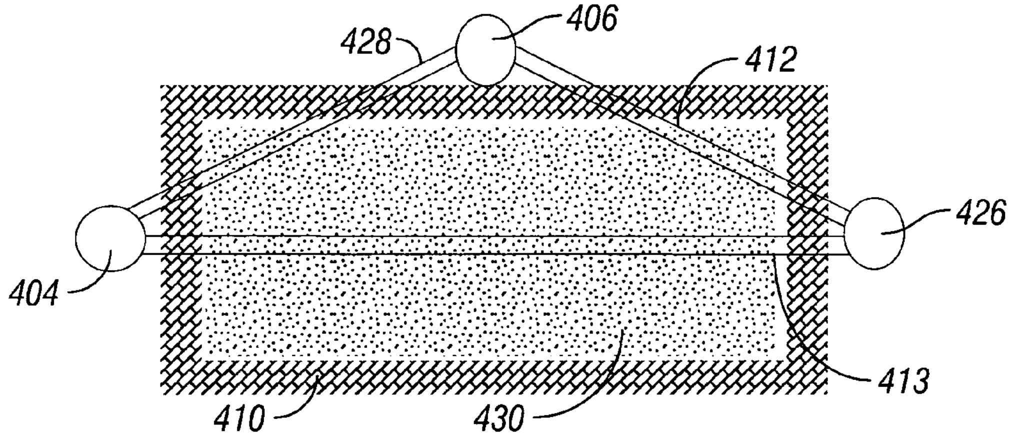

FIG. 4B

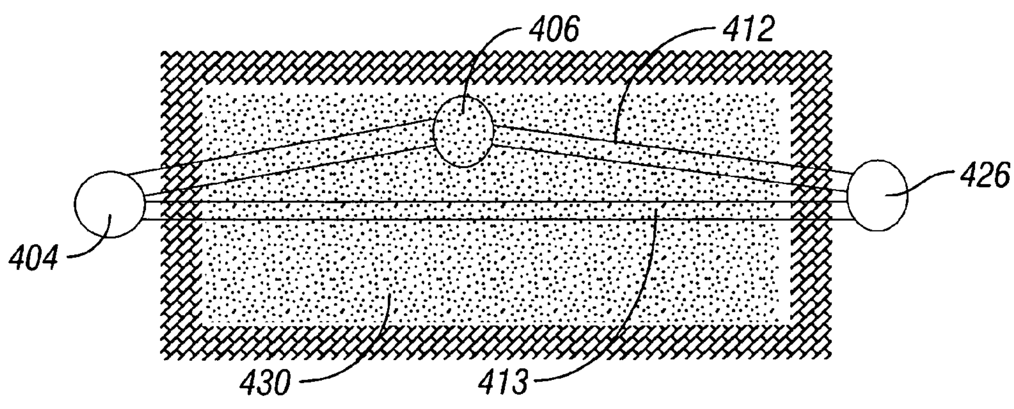

FIG. 4C

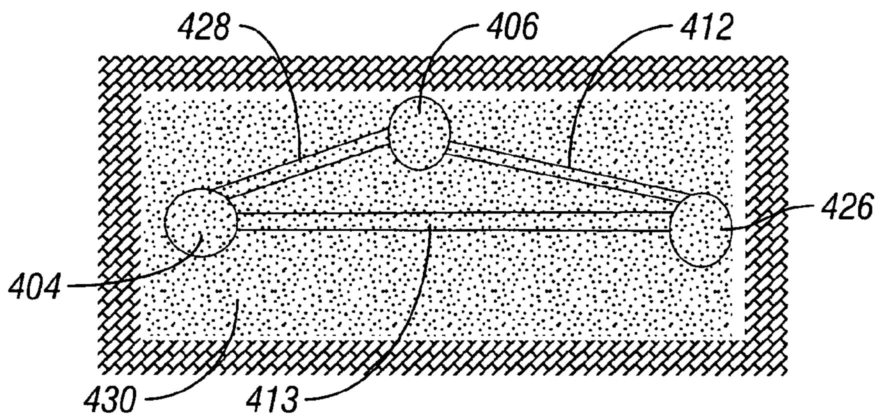

FIG. 4D

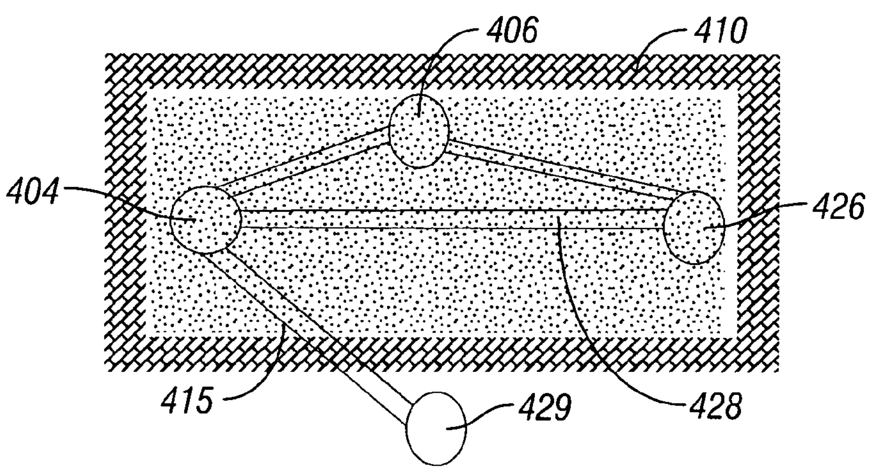

FIG. 4E

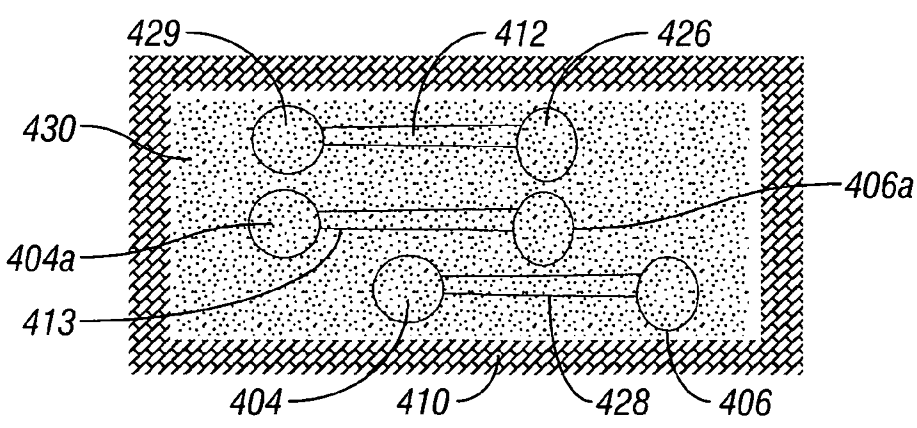

FIG. 4F

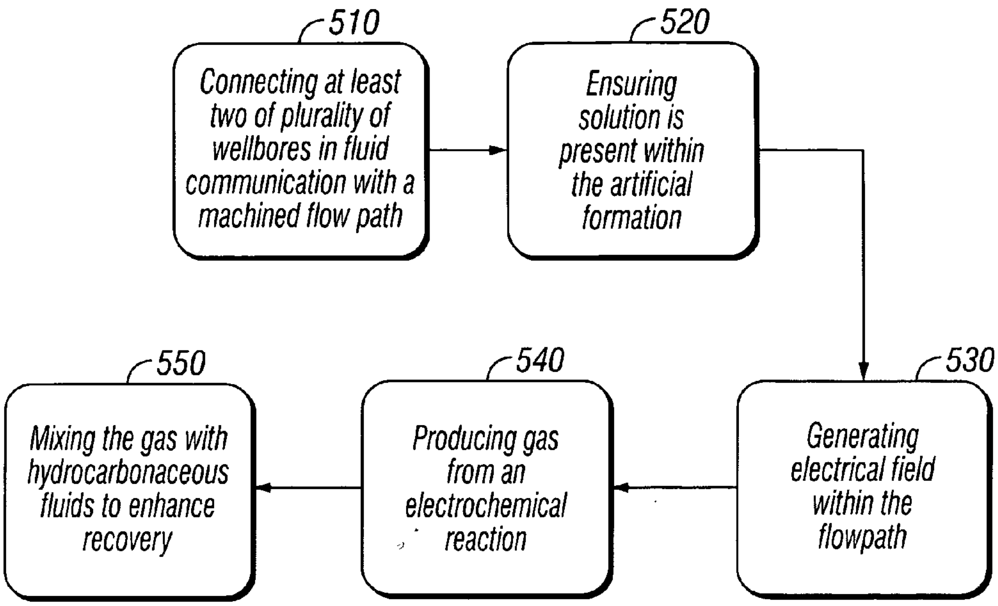
510
Connecting at least two of plurality of wellbores in fluid communication with a machined flow path
520
Ensuring solution is present within the artificial formation
530
Generating electrical field within the flowpath
540
Producing gas from an electrochemical reaction
550
Mixing the gas with hydrocarbonaceous fluids to enhance recovery

FIG. 5A

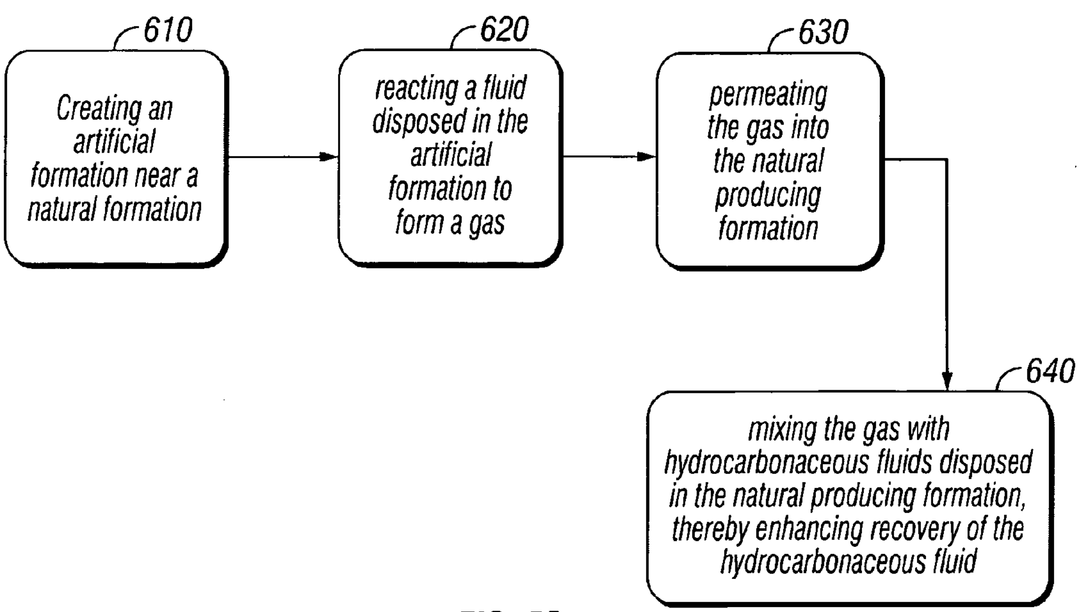
610
Creating an artificial formation near a natural formation
620
reacting a fluid disposed in the artificial formation to form a gas
630
permeating the gas into the natural producing formation
640
mixing the gas with hydrocarbonaceous fluids disposed in the natural producing formation, thereby enhancing recovery of the hydrocarbonaceous fluid

FIG. 5B

SYSTEMS AND METHODS FOR ENHANCED RECOVERY OF HYDROCARBONACEOUS FLUIDS

BACKGROUND OF THE DISCLOSURE

[0001] 1. Field of the Disclosure

[0002] Embodiments disclosed herein generally relate to systems and methods that enhance the recovery of hydrocarbonaceous fluids. Specific embodiments relate to systems and methods to stimulate a producing formation by using a gas generated from an electrochemical reaction. Other embodiments relate to the use of AC electrolysis in a machined formation adjacent to and/or within a producing formation to generate a gas that permeates into hydrocarbonaceous fluids disposed in the producing formation.

[0003] 2. Description of the Related Art

[0004] Large deposits of hydrocarbonaceous fluids, such as crude oil, are known to exist in subterranean formations throughout the world. In the past, these fluids were recovered from the formations until the natural energy (e.g., pressure) of the formation expired, at which point the formation was typically abandoned. This primary recovery typically produced as little as 15%-25% of the hydrocarbonaceous fluids within the formation, with the large majority of hydrocarbons left unrecovered because the economic cost of continued production exceeded the value of the quantity of hydrocarbonaceous fluids recovered. As the value of hydrocarbonaceous fluids increased, secondary recovery processes became economically justifiable for use to increase production from formations.

[0005] Secondary recovery may include, for example, a pumping operation that draws previously unrecoverable fluids to the surface. However, these processes vary greatly, as processes that enable successful recovery from one or more formations may not be economical and/or successful when used in conjunction with other formations. In addition, the capabilities of secondary recovery methods are limited. For example, formations that contain hydrocarbonaceous fluids with a low specific gravity, and/or high viscosity, and possess little or no natural energy may be unaffected by secondary recovery. In the absence of formation pressure, even fluids of average viscosity and specific gravity are difficult to produce through secondary recovery methods without addition of external energy to the formation.

[0006] As such, a great deal of attention has recently been given to various methods of tertiary recovery. Logically, an abundance of tertiary recovery processes consider energy-based techniques that increase the temperature (i.e., reduce viscosity) and/or the pressure of the producing formation, thereby increasing flowabilitiy. For example, "fire flooding" employs the technique of burning oil "in situ" or within the formation, thereby heating the formation and pressurizing the formation with resultant hot combustion gases.

[0007] Gas injection is another example of a tertiary process. Under injection pressures, CO_2 gas may be solvent with hydrocarbonaceous fluids, which increases the actual volume of the fluids and also reduces specific gravity and viscosity. Thus, the solvency of the injected gas provides increased formation pressure and less viscous hydrocarbonaceous fluids. CO_2 injection into the formation also causes the hydrocarbonaceous fluids to "break out" of the formation matrix, and thereby further promotes increased production. Nevertheless, many tertiary processes, such as gas injection, require extensive and/or cost-prohibitive surface equipment and operations, and may also cause damage to the producing formation that hinders or terminates future production ability.

[0008] Some economical tertiary processes include introducing an electric current into the producing formation to cause exothermal heating of the surrounding formation, which lowers the viscosity of hydrocarbonaceous fluids and stimulates flow. Typically, electrodes are connected to an electrical power source and are positioned at spaced apart points within the producing formation, whereby single electrodes are usually disposed in a corresponding wellbore that penetrates into the producing formation. When current passes between the electrodes and the formation, high resistance of the formation causes power to dissipate, which results in a power loss that heats the producing formation and hydrocarbonaceous fluids. However, this process is generally limited to the immediate area involved in the heating process.

[0009] There is a need for economical and readily useable enhanced recovery systems and methods that beneficially use an electrochemical reaction, but do not require constituent elements within the producing formation. There is a need for an electrochemical reaction that may generate a gas that permeates and/or mixes with formation fluids, whereby the pressure of the producing formation may be increased and/or viscosity of hydrocarbonaceous fluids reduced, thereby increasing flowability. There is also a need to monitor and optimize systems and methods that use an electrochemical reaction to enhance recovery of hydrocarbonaceous fluids. Other needs addressed by embodiments disclosed herein include the ability to convert clean renewable energy into ~100% usable energy.

SUMMARY OF THE DISCLOSURE

[0010] Embodiments of the present disclosure relate, generally, to systems and methods for enhanced recovery of hydrocarbonaceous fluids. Electrodes may be provided into two or more wellbores. The wellbores may include preexisting producing and/or abandoned wellbores, naturally occurring features, or additional wellbores that may be drilled, machined, or otherwise formed to facilitate performance of the enhanced recovery process described herein.

[0011] The wellbores may then be placed in fluid communication through the creation of a machined flow path therebetween. For example, horizontal drilling or similar methods for forming flow paths may be used to connect two or more wellbores. In an embodiment of the disclosure, three wellbores having electrodes therein may each be provided in fluid communication with one another. It should be understood that any configuration of wellbores and electrodes may be used, such that at least two wellbores having electrodes therein are provided in fluid communication.

[0012] A solution, such as brine or a similar generally conductive fluid, is pumped or otherwise provided within the machined flow path, such that the electrodes extend at least partially therein. A power source operatively connected to the electrodes is then actuated to produce an electrical field therebetween. In an embodiment of the disclosure, generation of the electrical field may include application of alternating current to the solution.

[0013] The electrical field causes an electrochemical reaction within the solution to create a gas that may solvently mix with in situ hydrocarbonaceous fluids, thereby increasing pressure within the formation and/or decreasing the viscosity of the hydrocarbonaceous fluids. As one example, brine may be provided into the machined flowpath, and the electrochemical reaction may form hydrogen gas. The formed gas may freely pass into adjacent formations containing hydrocarbonaceous fluids, mix with hydrocarbonaceous fluids to reduce the viscosity thereof, and increase pressure within the machined flowpath, wellbores, and/or adjacent formations.

[0014] An alternate embodiment may include creating an artificial subterranean formation at least partially underneath a producing and/or abandoned formation containing hydrocarbonaceous fluids. A fluid, such as brine, disposed in the artificial formation may be reacted to form a gas (i.e., hydrogen), which may permeate into the producing formation to increase the pressure therein and/or decrease viscosity of the hydrocarbonaceous fluids.

[0015] Embodiments disclosed herein may be used to increase a formation pressure, or otherwise alter flow characteristics of fluids in the formation. This may include, for example, a tertiary recovery process that establishes an electrical current flow within a formation via one or more electrodes that extend into the formation. The current flow may generate a zone of electrochemical activity in the formation that causes an electrochemical reaction with solutions disposed in the formation, thereby generating volumes of free gases to increase the formation pressure.

[0016] The electrochemical activity further enhances flow characteristics of formation fluids by lowering the viscosity of the fluids. The increased formation pressure acts to drive the hydrocarbonaceous fluids into a producing wellbore. The process may also release fluids from the earth formation matrix that are within the zone of electrochemical activity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIGS. **1**A and **1**B depict multiple views of a various embodiments of a system for enhanced recovery of hydrocarbonaceous fluids, useable within the scope of the present disclosure.

[0018] FIG. **1**C shows a cross-sectional view of a conduit useable in one of the systems of FIGS. **1**A and **1**B, within the scope of the present disclosure.

[0019] FIG. **2** depicts a side view of an embodiment of a system for enhanced recovery of a producing formation separate from a non-producing formation, useable within the scope of the present disclosure.

[0020] FIG. **3** depicts a side view of an alternate embodiment of a system for enhanced recovery of hydrocarbonaceous fluids, useable within the scope of the present disclosure.

[0021] FIGS. **4**A, **4**B, **4**C, **4**D, **4**E, and **4**F depict multiple partial downward sectional views of various embodied arrangements of systems useable to enhance recovery of hydrocarbonaceous fluids, in accordance with the scope of the present disclosure.

[0022] FIGS. **5**A and **5**B depict flow charts illustrating embodiments of methods for enhanced recovery of hydrocarbonaceous fluids, useable within the scope of the present disclosure.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] Embodiments of the present disclosure will now be described in detail with reference to the accompanying Figures, which may include like elements in various Figures denoted by like reference numerals for consistency. The detailed description may also set forth numerous specific details in order to provide a more thorough understanding of the claimed subject matter. However, it should be apparent to one of ordinary skill in the art that the embodiments described may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid unnecessarily complicating the description.

[0024] In addition, directional terms, such as "above," "below," "upper," "lower," etc., are used for convenience in referring to the accompanying drawings. In general, "above," "upper," "upward," and similar terms refer to a direction toward the earth's surface from below the surface along a wellbore, and "below," "lower," "downward," and similar terms refer to a direction away from the surface along the wellbore (i.e., into the wellbore), but is meant for illustrative purposes only, and the terms are not meant to limit the disclosure.

[0025] Referring now to FIGS. **1**A, **1**B, and **1**C, multiple side views of various embodiments of a system **100** for enhanced recovery of hydrocarbonaceous fluids according to the present disclosure, is shown. FIG. **1**A shows the system **100** may include features and components readily recognized by one of skill in the art, such as a surface production facility **102** that produces hydrocarbonaceous fluids **130** from a producing formation **110** by way of a wellbore **108**. The producing formation **110** may be surrounded by various non-producing formations, such as overburden **114**, bed rock **116**, and/or other earthen material **118**.

[0026] A producing formation may be a formation that produces appreciable amounts of hydrocarbonaceous fluids as a result of primary, secondary, and/or tertiary recovery processes. An appreciable amount of produced fluid may be, for example, one or more barrels a day. A non-producing formation may be a formation incapable of producing appreciable amounts of hydrocarbonaceous fluids from primary, secondary, and/or tertiary recovery means. An artificial (e.g., man-made, machined, drilled, etc.) formation may advantageously be formed in the producing formation, the non-producing formation, or combinations thereof.

[0027] For a formation to be productive, a pressure differential must exist between the producing formation and the wellbore. Energy for the pressure differential may be supplied naturally in the form of gas, either free or in solution, evolved under a reduction in pressure. Where the natural energy forces within the producing formation are insufficient to overcome any retardant forces within the formation, external energy must be added.

[0028] Thus, to enhance the recovery of the producing formation **110**, an artificial formation **112** may be formed within (e.g., in the vicinity of, as part of, etc.) the producing formation **110**, which may include, for example, a plurality of wellbores drilled therein. In one embodiment, the artificial formation **112** may include a first wellbore **104** in fluid communication with a second wellbore **106**, with a conduit **128** formed therebetween.

[0029] Wellbores **104**, **106** and conduit **128** may be formed with conventional drilling methods, such that the wellbores **104**, **106** and conduit **128** may be pressurized (including use of wellheads **122**, etc.), cased, cemented, perforated, etc., as would be understood to one of skill in the art. In one embodiment, the conduit **128** may be a substantially horizontally drilled wellbore. It should be understood that in select embodiments, at least part of the artificial formation **112** may be left uncased, uncemented, or otherwise unmodified. For example, the conduit **128** may be drilled through stable strata of the producing formation **110**, such that casing and/or cementing is not required.

[0030] In one embodiment, the wellbores **104**, **106** and/or the conduit **128** may be at least partially disposed within or through the producing formation **110**, such that the wellbores **104**, **106** and/or conduit **128** are independently or simultaneously useable for production of hydrocarbonaceous fluids **130**. The artificial formation **112** may be formed in the presence of pre-existing aqueous solutions, such as saltwater, brine, etc. Alternatively, one or more pumps **120** may be configured to convey a surface solution from a source (not shown) to the artificial formation **112**. The source may include, for example, a storage tank at the surface or an underground reservoir in communication with the pump.

[0031] The artificial formation **112**, including any of the formation **112** components, such as conduit **128**, may be formed in any portion of the producing formation **110**. Although FIG. **1**A illustrates the conduit **128** near the bottom of the producing formation **110**, the conduit **128** may be formed through a middle region, or through an upper region (near the overburden **114** or the surface), such that the location of where the conduit **128** is formed is not meant to be limited to any specific location. FIG. **1**B illustrates by way of example the conduit **128** may be disposed in a general middle region of the producing formation **110**.

[0032] The producing formation **110** may be configured with a fresh water flood or a gas injection process (e.g., carbon dioxide injection), such that embodiments disclosed herein may readily provide for the conversion of these processes to that of a saltwater flood (or flood with other comparable electrolyte). The saltwater flood may be accomplished to provide an electrolytic path formed within the producing formation **110**.

[0033] The wellbores **104**, **106** may each have an electrode **132** disposed therein. As illustrated, the electrodes **132** may be located near the bottom of the wellbores **104**, **106**, such that the electrodes **132** may extend at least partially into the solution **138**. Although FIGS. **1**A and **1**B illustrate two electrodes **132**, it should be understood that any number and configuration of electrodes **132** within any number or configuration of wellbores may be provided in contact with the solution **138**.

[0034] Any of the electrodes **132** may be made of electrically conducting materials, such as, for example, aluminum or stainless steel. However, other materials are also possible, such as graphite or other semi-conductive material. As an example, the electrodes may be any type of electrode known in the industry, such as the electrode(s) described in either of U.S. Pat. Nos. 4,084,639 and 4,199,025 incorporated by reference herein in entirety. The electrodes **132** may be, for example, metallic electrodes that are long enough so that the lower ends of each may be immersed in the solution **138**. The upper ends of the electrodes **132** may be connected by suitable leads (not shown) to an electrical power source **124**.

[0035] The electrodes **132** may be disposed within the wellbores **104**, **106** (and any solution **138** present in the wellbores) in any fashion. For example, the electrodes **132** may be coupled to the end of a tube string **133** or similar elongate member. The tube string **133** may include various components, such as downhole tools, sliding sleeves, conduits, connectors, etc. The tube string **133** may include portions that are configured with electrically non-conducting material, such as fiberglass, plastic, or other generally non-conductive materials.

[0036] Hydrocarbonaceous fluids are generally poor conductors, while an electrolyte, such as brine, is a good conductor. Since an electric current will follow the path of least resistance, current applied to the electrodes **132** will flow directly through the solution **138** that is between the electrodes **132**. The flow of current may tend to heat the solution **138** in accordance with the amount of solution **138** disposed therebetween, as well as the magnitude of current being applied to the electrodes **132**. The heated solution may function as a heater with respect to the fluids **130** within the producing formation **110**, whereby the viscosity of the fluids **130** may be decreased, and the flow characteristics of the fluids **130** in the formation **110** may be enhanced.

[0037] The electrodes **132** may be operatively connected with a power source **124**, which may be located at the surface or another location in electrical communication with the electrodes **132**. The power source **124** may be used to create an electric field via an electric circuit created by the power source **124**, electrodes **132**, and solution **138**, as described below. The power source **124** may be of appropriate size and capacity in order to generate electric current that may be conducted into the wellbores **104**, **106**, and into the solution **138**. Components connected between the power source, the wellbores, the electrodes, etc., may be fully insulated from any of the formation(s) in order to isolate the electrical current path.

[0038] In one embodiment, the power source **124** may be any conventional power source, such as a battery or steam/furnace turbine-generator. In another embodiment, the power source **124** may be a non-conventional power source, such as a renewable (i.e., green, clean, etc.) energy source. For example, there may be one or more wind turbines that together may collectively form a wind farm (not shown).

[0039] As known to one of ordinary skill in the art, a wind farm may be a group of wind turbines in the same approximate location that may be used for production of electric power. Individual turbines may be interconnected with a voltage power collection system, whereby electrical current that is produced by the turbines may be transferred from the wind farm (via the power system) to the electrodes **132**, and into the solution **138**. Thus, with a renewable source, "green" energy is used, thereby eliminating the need to obtain power from a conventional source (e.g., burning fossil fuels). Furthermore, the ability to store and/or covert the green energy into formation energy (i.e., increased formation pressure and/or decreased viscosity) is advantageous compared to other renewable energy processes that lose energy by inefficient mechanical processes and/or transfer of energy to an energy grid.

[0040] In some embodiments, any of the wellbores may be formed with perforations (not shown), which may be present in the casing and/or the artificial formation **112**. The perforations may allow injection of brine or other fluids from the surface into the artificial formation **112**. As such, the electrodes **132** may also have perforations disposed therein. Accordingly, fluid injection may occur by the conveyance of pressurized fluid through the tube string **133**, out the electrode perforations, and into the artificial formation **112**.

[0041] In some embodiments, depending on the construction of conduit **128**, the wellbores **104**, **106** may allow fluids **130** from the producing formation **110** to enter the wellbores and make contact with electrodes **132**. Upon application of the electrical current from the power source **124** to the electrodes, an electric current may be passed between the electrodes **132**, and into the producing formation **110**.

[0042] The action of the electrical current passing through the circuit formed by the electrodes **132**, the power source **124**, and the solution **138** may heat the formation(s) **110** and/or **112** as a result of the resistive properties of solution **138** and formation(s) **110** and/or **112**. In addition, the electrochemical reactions may provide increased internal pressure within the formation **110** to thereby drive hydrocarbonaceous fluids **130** into a producing wellbore **108**. The electrochemical reaction may, for example, increase the formation pressure as much as 300 psi over a large area.

[0043] The electrochemical action within the formation(s) may produce at least the following phenomena:

[0044] i) reduction in the viscosity and specific gravity of the hydrocarbonaceous fluids in the formation, thereby enhancing the flow characteristics of the fluids;

[0045] ii) generation of large volumes of free gas in the formation due to electrochemical action with the solution; iii) release of the hydrocarbonaceous fluids from the earth formation matrix; and

[0046] iv) production of heat within the formation matrix in the area traversed by the current.

[0047] As shown by FIG. **1**C, pressure within the wellbore (s) may be sufficient enough to disperse solution **138** (and/or gas formed by electrolysis) out into the producing formation **110**. In one embodiment, the solution **138** may disperse outwardly from the artificial formation **112** in any direction. This may result, in one example, because the pressure within the producing formation **110** is insufficient to drive fluids **130** into the artificial formation **112**. Conversely, pressure within the artificial formation **112**, as a result of increased pressure, such as from pump **120**, may cause fluids within the artificial formation **112** to enter the producing formation **110**. The dispersal of fluid from the conduit **128** may be, for example, in any outward direction from the conduit **128**, including 360-degree radial direction.

[0048] The ability to drive solution **138** into the producing formation **110** helps broaden the area of where the electrolysis process may occur. Thus, the electrochemical reaction may occur within the formation **110** in an area that is much greater than the area defined by the conduit **128**. The extra pressure of the solution **138** (via the pressurization of the artificial formation **112**) may also provide additional pressure to the formation **110**. This may create a synergistic effect that helps further enhance the recovery of the hydrocarbonaceous fluids **130** because the extra pressure facilitates the movement of the fluids **130** toward the wellbore **108**.

[0049] Referring now to FIG. **2**, an embodiment of a system for enhanced recovery of a producing formation separate from a non-producing formation according to embodiments of the present disclosure, is shown. System **200**, which may be of a similar construction and/or configuration as the system of FIG. **1**, may include a surface production facility **202** that produces hydrocarbonaceous fluids **230** from a producing formation **210** by way of a wellbore **208**. The producing formation **210** may be surrounded by one or more non-producing formations, such as overburden **214**, bed rock **216**, and/or other earthen material **218**.

[0050] To enhance the recovery of the producing formation **210**, a non-producing artificial formation **212** may be created adjacent (e.g., in the vicinity of, next to, separate from, etc.) and external to the producing formation **210**. The artificial formation **212** may include, for example, a plurality of wellbores drilled therein. Thus, in one embodiment, the artificial formation **212** may include a first wellbore **204** in fluid communication with a second wellbore **206**, with a conduit **228** formed therebetween.

[0051] In some embodiments, the artificial formation **212** may be formed in the presence of pre-existing aqueous solutions, or there may be one or more prime movers (e.g., a pump) **220** configured to convey a surface solution from a source (not shown) to the artificial formation **212**. Thus, the wellbores **204**, **206** and/or the conduit **228** may have an aqueous solution **238** disposed therein, and each of the wellbores may have an electrode **232** disposed therein and in electrical communication with the solution **238**, as previously described.

[0052] In other embodiments, any of the wellbores may be formed with perforations (not shown), which may be present in the casing and/or the artificial formation **212**. The perforations may allow injection of brine or other fluids from the surface into the artificial formation **212**. As such, the electrodes **232** may also have perforations disposed therein. Accordingly, fluid injection may occur by the conveyance of pressurized fluid through a tube string **233**, out the electrode perforations, and into the artificial formation **212**.

[0053] Although not illustrated, the wellbores **204**, **206** and/or the conduit **228** may be at least partially disposed within or through the producing formation **110**, such that the wellbores **204**, **206** and/or conduit **228** are independently or simultaneously useable for production of hydrocarbonaceous fluids **230**, in addition to creation of the electric field within the solution **238**. Thus, a non-producing artificial formation may be converted to a producing artificial formation, if desired.

[0054] Referring now to FIG. **3**, a side view of an alternate embodiment of a system for enhanced recovery of hydrocarbonaceous fluids is shown. System **300**, which may be of similar construction and/or configuration as the system of FIG. **1** or **2**, may include a surface production facility **302** that produces hydrocarbonaceous fluids **330** from a producing formation **310** by way of a wellbore **308**. The producing formation **310** may be surrounded by one or more non-producing formations, such as overburden **314**, bed rock **316**, and/or other earthen material **318**.

[0055] FIG. **3** depicts an artificial formation **312** formed adjacent to the producing formation **310**, which may be conditioned using methods such as fracturing, acidizing, etc., that may facilitate creation of the artificial formation **312**. The artificial formation **312** may include various structures, such as, for example, at least two wellbores **304**, **306** and a conduit **328**. The wellbores **304**, **306** and/or the conduit **328** may have a solution **338** disposed therein, the solution **338** including a pre-existing body of solution, or provided using one or more pumps **320**, as described previously. As such, any of the wellbores **304**, **306** may be useable to convey fluids to or from the artificial formation **312**.

[0056] FIG. **3** also depicts a third wellbore **326**, which may be drilled, at least partially, through the producing formation **310** and into the artificial formation **312**. In one embodiment, the third wellbore **326** may include a preexisting wellbore used to recover hydrocarbonaceous fluids from the producing formation **310**. Accordingly, drilling operations may be used to extend the third wellbore **326** beyond the producing formation **310**, while preexisting or additional cementing and/or casing may be used to selectively isolate the third wellbore **326** from the producing formation **310**. Thus, the third wellbore **326** may be in fluid communication with the artificial formation **312**, isolated from the producing formation **310**, or combinations thereof.

[0057] The wellbores **304**, **306**, **326** may each have an electrode **332** disposed therein, such that any of the electrodes **332** may extend at least partially into the solution **338**. It should be appreciated that one or more of the electrodes may function as a cathode **334**, and one or more of the electrodes **332** may function as an anode **333**, the operation of which would be known to one of skill in the art. The electrodes **332** may be operatively connected with a power source **324**, such as a DC power source or an AC power source, which may be located, for example, at the surface. In one embodiment, the power source **324** may generate single-phase AC. In another embodiment, the power source **324** may generate three-phase AC. The AC signal may be, for example, rectangular, sinusoidal, sawtooth, etc.

[0058] The power source **324** may be used to create an electric field through the use of an electric circuit created between the power source **324**, electrodes **332**, and solution **338**, and may include any of the power sources previously described, but is not meant to be limited. Gas may be produced in the artificial formation **312** by an electrolysis process, which may generally be understood as a process that uses an electric current to drive an otherwise non-spontaneous chemical reaction in a medium that contains mobile ions, such as an electrolyte. In this case, the medium may be the solution **338**, which may include, for example, salt water or brine.

[0059] As such, the electrodes **332** may provide an electrical interface between the power source **324** and the solution **338**. In this manner, the power source **324** may be configured to provide the energy to achieve the electrolysis, the further details of which would be understood by one of ordinary skill in the art. Accordingly, generation of an electric field within the solution **338** may initiate a region of exothermic electrochemical reaction at the electrodes **332**, in the solution **338**, in the artificial formation **312**, and combinations thereof.

[0060] The producing formation **310** may include earthen material that has a porosity sufficient to maintain the hydrocarbonaceous fluids **330** within the producing formation **310**, while permitting gas from the artificial formation **312** to permeate into the producing formation so that the gas may solvently mix with hydrocarbonaceous fluids **330**. As such, generated gas is released from the solution **338** may permeate from the artificial formation **312** into the producing formation **310**.

[0061] For example, in a solution of brine, hydrogen gas may be generated, as illustrated by Equation 1 below:

$$2NaCl+2H_2O \rightarrow 2NaOH+H_2Cl_2 \quad [1]$$

[0062] As hydrogen gas is generated, hydrogen molecules, as a result of the molecules' small size and inherent properties, may permeate through the artificial formation, the producing formation, and into the hydrocarbonaceous fluids. Permeation of hydrogen molecules, or another similar gas, into the hydrocarbonaceous fluids, may decrease the viscosity of the hydrocarbonaceous fluids and increase pressure within the producing formation **310** to enhance and/or enable production of the hydrocarbonaceous fluids. If necessary, the artificial formation **312** may be maintained at a selected pressure to facilitate permeation of the gas into the producing formation **310**.

[0063] Any components of the system, including the producing and non-producing formations, may be configured with monitoring and sensor capability (not shown), such that the recovery and/or overall operation of the system may be measured, as would be known to one of skill in the art. As such, the system may be optimized as a result of system measurements and analysis thereof. The optimization may include select adjustment of system variables, such as the electric field generated by the power source. For example, the electric field may be adjusted by changing at least one of a current, a voltage, a frequency, and combinations thereof. Other methods of optimization are possible in view of the embodiments described herein.

[0064] Because the reaction is exothermic, an additional synergistic effect of the reaction may include dissipation of heat into the formation that further reduces the viscosity of the formation fluids, and further increases pressure in the formation, due to the additional volume of the gas at the heated temperature. The increased volume of the formation fluids may also "break out" hydrocarbonaceous fluids from formation matrix, whereby the fluids may flow more readily toward the producing wellbore. As a result of increased pressure and reduced viscosity, the hydrocarbonaceous fluids may flow more readily toward the producing wellbore **308**, and the fluids may be easier and therefore cheaper to recover to the surface.

[0065] Referring briefly to FIGS. **4**A, **4**B, **4**C, **4**D, **4**E, and **4**F multiple partial downward views of various embodiments of systems useable to enhance recovery of hydrocarbonaceous fluids, according to embodiments of the present disclosure, are shown. FIG. **4**A shows a system **400**, which may include various features and components previously described but not shown, that may be used to produce hydrocarbonaceous fluids **430** from a producing formation **410** by way of a wellbore. The producing formation **410** may be surrounded by non-producing formations, such as an overburden, bed rock, and/or other earthen material (not shown).

[0066] As may be seen, there may be a plurality of wellbores disposed within or external of the producing formation **410**. In the embodiment depicted, an artificial formation may be formed that includes a first wellbore **404** in fluid communication with a second wellbore **406**. Fluid communication between the wellbores **404**, **406** may be provided, for example, by conduit **428**. Additional wellbores may be provided, such as, for example, a wellbore **426**, that is part of the system **400**, but is not in fluid communication with other wellbores **404**, **406**; however, it should be understood that another conduit (not shown) may be drilled to connect the wellbore **426** with other wellbores **404**, **406** and the conduit **428**, as desired.

[0067] The wellbores **404**, **406**, and/or the conduit **428** may have a solution disposed therein, and any of the wellbores that are part of the artificial formation may be used to convey fluids into or from the artificial formation. The wellbores **404**, **406**, may be configured with an electrode (**132**, FIG. **1**A, **1**B) disposed therein. As previously described, the electrodes may be used in conjunction with the solution (**138**, FIG. **1**A, **1**B) to carry out an electrolysis process.

[0068] FIGS. **4**B-**4**F together illustrate operational variants of system **400**. FIG. **4**B shows each of the wellbores **404**, **406**, and **426** in fluid communication. The artificial formation is shown including a first conduit **428** formed, at least partially, under the producing formation **410**. Alternatively, or in addition, there may be a second conduit **412** and a third conduit **413** formed, at least partially, under the producing formation **410**.

[0069] Although not illustrated here, the location of the bottom of any of the wellbores and/or conduits may be as previously described. For example, the bottom of the wellbores **404**, **406**, **426**, etc., may fully reside within the producing formation **410**. Similarly, conduit **428** may also fully reside within the producing formation **410**. In one embodiment, conduit **428** may be a substantially horizontally drilled wellbore. FIG. **4**D illustrates wellbores **404**, **406**, and **426**, as well as conduits **428**, **412**, and **413**, disposed within the producing formation **410**. Alternatively, the wellbores and connecting conduits may define an artificial formation, which in one embodiment, may reside within, but are fluidly isolated from, the producing formation **410**.

[0070] FIG. **4**C analogously illustrates an embodiment of the system **400**. Specifically, the system **400** is shown including wellbores **404**, **426** disposed external of the producing formation **410**, and a wellbore **406** disposed, at least partially, through the producing formation **410**. In an embodiment, wellbore **406** disposed at least partially through the producing formation **410** may include a previously producing wellbore. In a further embodiment, wellbore **406** may be simultaneously or sequentially used to produce the hydrocarbonaceous fluids **430**.

[0071] FIG. **4**E further illustrates an embodiment of the system **400** that includes a fourth wellbore **429** provided in fluid communication with the other wellbores **404**, **406**, **426** via a conduit **415**. FIG. **4**F depicts an alternate embodiment of system **400** whereby wellbores and conduits may be in separately isolated fluid communication. For example, wellbores **404** and **406** may be in fluid communication as a result of conduit **428**, whereas wellbores **404***a* and **406***a* are separately connected with each other by conduit **413**.

[0072] It should be understood that the system **400** is not limited to any specific number or configuration of wellbores and/or electrodes **432**. Any number of wellbores may be configured in fluid communication or fluid isolation with or from other wellbores, as desired. Additionally, the configurations depicted are possible within the producing formation, or the configurations are possible within a non-producing formation that is adjacent and external to the producing formation, or combinations thereof.

[0073] Referring to FIG. **5**A, a flow chart illustrating an embodiment of a method for enhanced recovery of hydrocarbonaceous fluids according to embodiments of the present disclosure, is shown. As previously described, there may be a producing formation that has a number of producing wellbores used for the recovery of hydrocarbonaceous fluids from the formation. To enhance recovery of the producing formation, an artificial formation may be created adjacent to the producing formation.

[0074] The artificial formation may include a number of man-made or machined components, such as a plurality of wellbores and directionally drilled flow paths. Step **510** includes connecting at least two of the plurality of wellbores together in fluid communication with at least one of the flow paths. In some embodiments, at least one of the flow paths may be substantially horizontal. In other embodiments, there may be a plurality of wellbores formed and/or connected in a triangulated pattern. Thus, there may be fluid communication between at least three non-producing wellbores.

[0075] A solution may pre-exist within the artificial formation, or solution may be provided thereto, as shown by step **520**. Thus, the method may include providing a surface solution to any of the wellbores and/or flow paths within the artificial formation. The method may further include steps **530** and **540**, which provide for generating an electrical field within the flow path, thereby causing an electrochemical reaction to produce a gas from the solution. In one embodiment, the solution may be an electrolyte, such as brine. In another embodiment, the solution may help conduct electricity between any of the plurality of electrodes.

[0076] After producing the gas from the solution, the gas may permeate out from the artificial formation, and into the producing formation. Once the gas enters the producing formation, the gas may be solvent to and/or mix with the hydrocarbonaceous fluids, as indicated by step **550**. Accordingly, the production of gas may increase pressures within any part of the artificial formation, the producing formation, or combinations thereof, thereby enhancing recovery of the hydrocarbonaceous fluids.

[0077] The electrical field, and hence the electrochemical reaction, may occur as a result of a power source operably connected to a plurality electrodes. In other embodiments, the power source may be an AC source that provides alternating current to the solution. The power source may provide, for example, a voltage of predetermined magnitude, for example, up to several thousand volts. Once the power source is activated, a current flow of, for example, one thousand amperes may flow between electrodes. In an embodiment, the current may flow between the electrodes via a medium disposed in the artificial formation. In a further embodiment, the medium may be brine, and application of the electrical field applied to the brine may produce hydrogen gas.

[0078] Referring to FIG. **5**B, a flow chart illustrating multiple steps of an alternate method for tertiary recovery of hydrocarbonaceous fluids according to embodiments of the present disclosure, is shown. The method may include step **610** of creating an artificial subterranean formation at least partially underneath a non-artificial producing formation, step **620** reacting a solution disposed in the artificial formation to form a gas, and step **630** permeating the gas into the producing formation, such that the permeated gas in the producing formation increases pressure within the producing formation.

[0079] In an embodiment, the artificial subterranean formation may include three wellbores in fluid communication, such that a triangulated wellbore pattern may be formed. Each of the three wellbores may include electrodes disposed therein to provide polarization to the solution. In another embodiment, the artificial subterranean formation may include a plurality of wellbores, with at least two of the plurality of wellbores in fluid communication as a result of a horizontally drilled conduit formed directly underneath a natural producing formation.

[0080] Solution in the artificial formation may react to produce a gas as a result of an electrolysis process created by an electric field generated within the artificial subterranean formation. In one embodiment, the solution may be brine, and the produced gas may be hydrogen. However, the solution and produced gas are not meant to be limited, and there may be other solutions that produce other gases that are capable of permeating from the artificial formation into the producing formation. Step **640** provides for mixing the gas with hydrocarbonaceous fluids disposed in the natural producing formation, thereby enhancing recovery of the hydrocarbonaceous fluid.

[0081] The mixing of hydrogen gas into the hydrocarbonaceous fluids may advantageously increase the producing formation pressure, and may advantageously help release hydrocarbonaceous fluids from the formation matrix. Accordingly, gas may beneficially mix with the fluids thereby reducing the viscosity of the fluids. Production of gases within a producing formation may advantageously provide energy within the formation to repressure the formation if the natural energy is no longer adequate to overcome the resistive forces.

[0082] The electrochemical reaction of the present disclosure may advantageously occur within and/or outside the producing formation, such that the reaction does not depend on constituent elements within the producing formation. Accordingly, systems and methods of the present disclosure have no dependence on any formation properties. There may beneficially include measurement configurations for the select optimization of systems and methods described herein.

[0083] Embodiments disclosed herein may provide systems and methods for establishing an electrical field in a subsurface formation, and establishing in response to the electrical field, a zone of electrochemical activity that may result in an electrochemical reaction that increases the formation pressure, reduces the viscosity of any hydrocarbonaceous fluids in the formation, and enhances recovery of the hydrocarbonaceous fluids.

[0084] While the present disclosure has been described with respect to a limited number of embodiments, those skilled in the art having benefit of the present disclosure will appreciate that other embodiments may be devised which do not depart from the scope of the disclosure described herein. Accordingly, the scope of the disclosure should be limited only by the claims appended hereto.

What is claimed:

1. A system for enhanced recovery of hydrocarbonaceous fluids, the system comprising:

a first wellbore comprising a first electrode disposed therein;

a second wellbore comprising a second electrode disposed therein;

a machined flow path disposed in fluid communication with the first wellbore and the second wellbore;

a solution disposed within the machined flow path, wherein the first electrode and the second electrode extend at least partially into the solution; and

a power source operatively connected to the first electrode and the second electrode, and configured to produce an electrical field therebetween, wherein the electrical field causes an electrochemical reaction within the solution to create a gas for permeating hydrocarbonaceous fluids and for increasing pressure within at least one of the first wellbore, the second wellbore, the machined flow path, and combinations thereof, thereby enhancing recovery of the hydrocarbonaceous fluids.

2. The system of claim **1**, wherein the power source is configured to provide alternating current to the first electrode and the second electrode.

3. The system of claim **1**, further comprising at least one pump for providing the solution to the machined flow path.

4. The system of claim **1**, wherein the solution comprises brine, and the gas comprises hydrogen.

5. The system of claim **1**, wherein the machined flow path comprises a horizontally drilled conduit.

6. The system of claim **1**, further comprising a third wellbore comprising a third electrode disposed therein, wherein the machined flow path further provides fluid communication between the third wellbore and at least one of the first wellbore and the second wellbore.

7. The system of claim **6**, the system further comprising a producing formation and a non-producing formation external of the producing formation, wherein the hydrocarbonaceous fluids reside in the producing formation, and wherein the machined flow path resides in the non-producing formation.

8. The system of claim **6**, wherein the machined flow path further provides triangulated fluid communication between the first wellbore, the second wellbore, and the third wellbore.

9. The system of claim **7**, wherein the machined flow path is disposed substantially adjacent to a producing formation comprising hydrocarbonaceous fluids.

10. The system of claim **1**, the system further comprising a producing formation and a non-producing formation external of the producing formation, wherein the hydrocarbonaceous fluids reside in the producing formation, and wherein the machined flow path resides in the non-producing formation.

11. A method for enhanced recovery of hydrocarbonaceous fluids, the method comprising:

connecting each of a plurality of wellbores together in fluid communication with a machined flow path;

providing a surface fluid to the flow path; and

generating an electrical field within the flow path, thereby causing an electrochemical reaction to produce a gas from the fluid, wherein the gas mixes with hydrocarbonaceous fluids and increases pressure within at least one of the plurality of wellbores, the flow path, and combinations thereof, thereby enhancing recovery of the hydrocarbonaceous fluid.

12. The method of claim **11**, wherein the step of generating the electrical field comprises providing alternating current to the surface fluid.

13. The method of claim **12**, wherein the alternating current is produced from a renewable energy source.

14. The method of claim **11**, the method further comprising the steps of measuring the enhanced recovery, and optimizing the enhanced recovery by changing the electrical field through select adjustment of at least on of a voltage, a frequency, and combinations thereof.

15. The method of claim **11**, wherein the hydrocarbonaceous fluids reside in a producing formation, and wherein the machined flow path resides in a non-producing formation adjacent to the producing formation.

16. The method of claim **11**, wherein the step of connecting each of the plurality of wellbores comprises drilling a conduit to place each of the plurality of wellbores in fluid communication.

17. The method of claim **16**, wherein the step of drilling the conduit comprises drilling a substantially horizontal conduit.

18. The method of claim **11**, wherein the step of connecting each of the plurality of wellbores comprises providing a triangulated pattern of fluid communication between three wellbores.

19. The method of claim **11**, wherein the step of generating the electrical field comprises disposing a plurality of electrodes into the fluid, and wherein the fluid conducts the electrical field between the plurality of electrodes.

20. The method of claim **11**, wherein the step of providing the fluid to the flow path comprises providing brine to the flow path, and wherein the electrochemical reaction produces hydrogen gas as a result of applying the electrical field to the brine.

21. A method for tertiary recovery of hydrocarbonaceous fluids, the method comprising:

creating at least part of an artificial subterranean formation external to a natural producing formation;

reacting a fluid disposed in the artificial formation to form a gas;

permeating the gas into the natural producing formation, wherein the permeated gas in the natural producing formation increases pressure within the natural producing formation; and

mixing the gas with hydrocarbonaceous fluids disposed in the natural producing formation, thereby enhancing recovery of the hydrocarbonaceous fluid.

22. The method of claim **21**, wherein the artificial subterranean formation comprises three wellbores in fluid communication thereby forming a triangulated wellbore configuration, and wherein each of the three wellbores comprise electrodes disposed therein to provide polarization to the fluid.

23. The method of claim **22**, wherein the artificial formation is entirely external of the natural producing formation.

24. The method of claim **21**, wherein the artificial subterranean formation comprises a plurality of wellbores, and wherein at least two of the plurality of wellbores are in fluid communication by a horizontally drilled conduit formed substantially underneath the natural producing formation.

25. The method of claim **21**, wherein the artificial subterranean formation comprises a plurality of wellbores, and wherein at least two of the plurality of wellbores are in fluid communication by a horizontally drilled conduit formed substantially within the natural producing formation.

26. The method of claim **21**, wherein a renewable energy source produces a current usable to form an electric field within the artificial subterranean formation, and wherein the fluid reacts as a result of an electrolysis process created by the electric field.

27. The method of claim **21**, wherein the producing formation is configured for at least one of gas injection, water flooding, and combinations thereof.

28. The method of claim **21**, wherein the fluid comprises brine solution, and the gas comprises hydrogen.

29. The method of claim **21**, wherein the artificial formation is entirely external of the natural producing formation.

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