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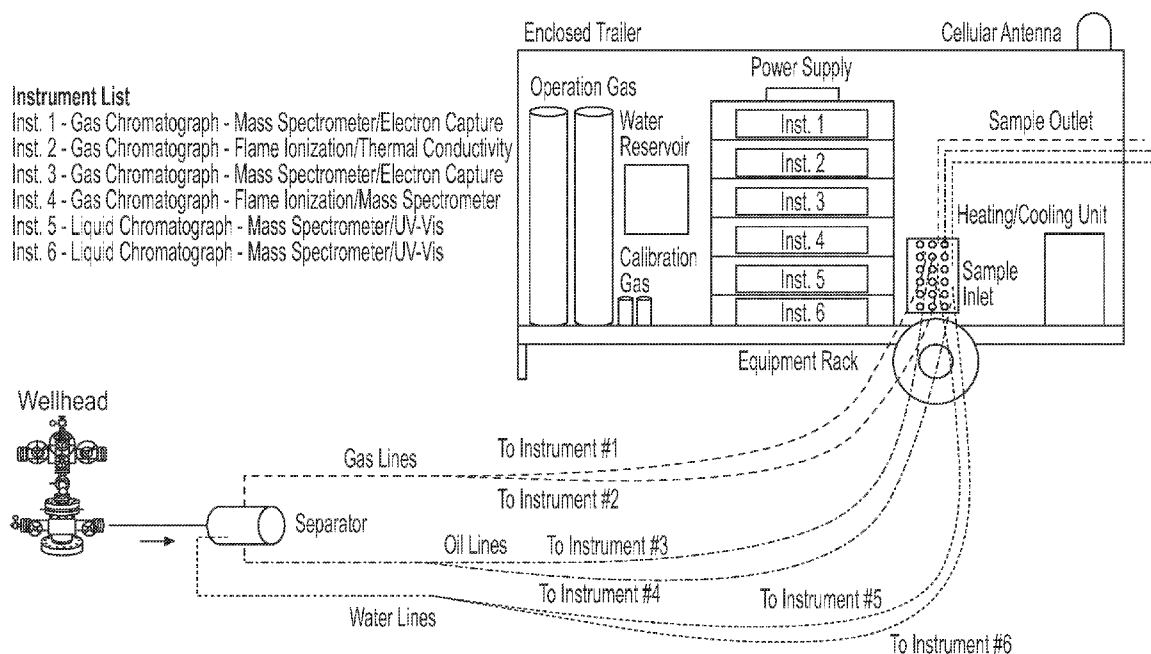


FIG. 3

(57) Abstract: An apparatus, system, compositions, and method to observe a sample from a wellbore traversing a subterranean formation including continuously collecting a sample from the wellbore, wherein the collecting comprises a separator and a valve, observing the sample in an instrument for characterizing the sample, wherein the instrument is enclosed in a housing, reporting a result of the observing, and controlling the temperature of the housing, instrument, sample, valve, or a combination thereof. An apparatus, system, compositions, and method to observe a sample from a wellbore traversing a subterranean formation including a sample continuously collected from the wellbore, wherein the sample flows through a separator and a valve, an instrument that characterizes the sample and records results of the characterizing, wherein the instrument is enclosed in a housing, a controller that controls the temperature of the housing, and a reporting device comprising a satellite system or a cellular router.

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DIAGNOSTIC PLATFORM DIRECTLY CONNECTED TO A SUBTERRANEAN FORMATION

Priority Claim

[001] This application claims priority to and the benefit of United States Provisional Patent Application Serial Number 63/472,492 filed June 12, 2023 with the same title, United States Provisional Patent Application Serial Number 63/519,169 filed August 11, 2023 with the same title, and United States Provisional Patent Application Serial Number 63/595,604 filed November 2, 2023 with the same title. All three of these applications are incorporated by reference herein in their entirety.

Background

[002] The use of diagnostics to inform the reservoir model is routine in the oil and gas industry. Insights as to the performance and connectedness of the reservoir can be obtained with tracers. Insights as to the producibility and connectedness of the reservoir can be obtained with geochemical analysis.

[003] Chemical tracers are soluble in the fluid they are meant to trace: oil, natural gas, and water. Tracer composition is tailored to be non-reactive with reservoir fluids or reservoir rocks, stable at downhole temperatures, and detectable at low concentrations, typically in parts per billion (ppb). Tracers are injected into the reservoir during hydraulic fracture stimulation or secondary recovery injections. Once placed in the reservoir, tracers will remain dissolved within the oil, gas, or water as the fluid is produced. Samples are taken of these produced fluids, transported to a lab, and analyzed for the tracer chemicals present and their concentration. Tracer chemical concentrations are proportional to the amount of fluid produced. The chemical identity and concentration test results are typically organized in time series charts and help inform models of the reservoir. The collection of samples, transport, lab analysis, and results reported back to the end user of the information has been in use with no noteworthy decrease in processing time for about half a century. The chemical identity and

concentration test results inform models of the reservoir into two major categories: flow profiles and interwell communication.

[004] Flow Profiles describe how portions of a well are flowing compared to each other. Profiles can be balanced, all segments are flowing evenly, or non-balanced, such as heel-dominated, where the heel portion of a horizontal well is flowing more than the toe portion. Flow profiles can be affected by hydraulic fracture treatment design and execution, changing reservoir geology, physical obstructions inside the wellbore, or reservoir drawdown intensity. They can and will change over time. Figure 1 shows a balanced flow profile from a well traced with 30 tracers. These data are invaluable as they inform technical personnel what is affecting the flow of the well, how to address it, and how it changes over time.

[005] Interwell communication describes how stimulation fluids flow in relation to wells over time. Tracers pumped in one well and recovered in another implies fluid communication through the reservoir. In secondary recovery operations, long-term well communication is preferred so that the injected fluids sweep more hydrocarbons. In hydraulically fractured wells, interwell communication can describe how the fracture system is propagating through the reservoir and traveling to another well, how natural fracture swarms or faults may magnify communication from one well to another, and how depleted reservoir rock affects fluid travel. Figure 2 shows the interwell communication of two wells each traced with four tracers. There are large concentrations of the tracers pumped in Well 1 being recovered in Well 2. On the other hand, there are small concentrations of tracers being recovered in Well 1 that were pumped in Well 2. The figure shows the preferential direction of the fluid, Well 1 to Well 2. These data are invaluable to technical personnel as they inform the reservoir model for the next set of operations in the area and how to optimize them.

[006] Geochemical analysis is the component analysis of water, oil and gas fluids produced from the reservoir. Samples of these produced fluids are taken from the wellsite, transported to a lab, and analyzed in a way similar to chemical tracers. The values and trends of the components over time are beneficial to the well operator for how much hydrocarbon is in place, how the profile of the produced hydrocarbons changes over time, and how offset wells in the reservoir affect the hydrocarbons being produced. Geochemical

analysis is used to allocate production for a group of wells that are in communication with each other from different producing formations. These data are also used to inform the reservoir model.

[007] In some embodiments engineers can use continuous oil and gas geochemical analysis to understand how a collection of wells in different reservoirs with different vertical depths are interacting. When a well begins production, its hydrocarbons come from the near-wellbore region. Then as the well begins to drain more of the reservoir the mechanism of production changes and the hydrocarbons flow from farther reaches of the reservoir into the wellbore. If there are multiple reservoirs being produced and those wellbores are connected, a wellbore in one reservoir may produce hydrocarbons from another reservoir depending on time, stimulated reservoir volume, well flowing conditions, and depletion effects. How these effects change over time are useful for engineers to design wellbore layouts, hydraulic fracturing treatments, flowback strategies, well interventions, and long-term production strategies.

Figures

- [008] Figure 1 is a schematic of a balanced flow profile for a 30 stage hydraulically fractured well.
- [009] Figure 2 is a schematic of interwell communication of two wells.
- [010] Figure 3 is a diagnostic platform schematic including sample flow from a wellhead to instruments in an equipment rack.
- [011] Figure 4 is a plot of tracer and cation concentrations as a function of time.
- [012] Figure 5 is a plot of tracer and cation concentrations as a function of time.
- [013] Figures 6A and 6B are schematic views of multiplexing valve inputs and outputs with a multiport dead-end configuration.
- [014] Figures 7A and 7B are schematic views of multiplexing valve inputs and outputs with a multiport flow through configuration.
- [015] Figure 8 is a diagnostic platform schematic including sample flow from two wellheads to instruments in an equipment rack
- [016] Figure 9 is a diagnostic platform schematic aligned with chromatograms and results.

- [017] Figure 10 is a plot of continuous water tracer and water cation concentrations.
- [018] Figure 11 is a plot of continuous oil tracer and oil component concentrations.
- [019] Figure 12 is a plot of continuous gas tracer and gas component concentrations.

Summary

- [020] Embodiments herein relate to an apparatus, system, compositions, and method to observe a sample from a wellbore traversing a subterranean formation including continuously collecting a sample from the wellbore, wherein the collecting includes a separator and a valve, observing the sample in an instrument for characterizing the sample, wherein the instrument is enclosed in a housing, reporting a result of the observing, and controlling the temperature of the housing, instrument, sample, valve, or a combination thereof. Continuously collecting a sample may include continuously flowing a portion of the sample through a port of the valve. The valve may be a multiport valve and it may have a flow through configuration. In some embodiments, the multiport valve has eight ports and it may accept samples from two wellbores. In some embodiments, the instrument may be a mass spectrometer with electron capture, flame ionization with thermal conductivity, flame ionization with mass spectrometer, mass spectrometer with UV-Vis, or a combination thereof. Further, reporting may include a satellite system, a cellular router, a controller, or a combination thereof. It may occur once every twenty-four hours and it may include results from two or more instruments. In some embodiments, reporting includes results from two or more instruments within the same hour. The housing may include a heating and cooling unit, a power supply, a water reservoir, operation gas, calibration gas, a sample outlet, or a combination thereof. In some embodiments, the separator separates the sample into gas, oil, water, or a combination thereof.
- [021] Embodiments herein relate to an apparatus, system, compositions, and method to observe a sample from a wellbore traversing a subterranean formation including a sample continuously collected from the wellbore, wherein the sample flows through a separator and a valve, an instrument that characterizes the sample and records results of the characterizing, wherein the instrument is enclosed in a housing, a controller that controls the temperature of the housing, and a reporting device comprising a satellite system or a cellular router.

Detailed Description

[022] This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

[023] As used in this document, the singular forms “a,” “an,” and “the” include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term “comprising” means “including, but not limited to.”

[024] Embodiments herein relate to collecting continuous information at the wellsite that informs the management of a producing reservoir. By directly connecting a diagnostic platform to the reservoir, engineers have a system to optimize well performance, map well-to-well connections, quantify the impact of well design changes, quantify the impact of hydraulic fracturing on offset wells, track production components and how they change over time, delineate depletion effects, and better produce mature fields under secondary recovery.

[025] In some embodiments, continuous geochemical analysis is applied to hydrocarbon samples in early time production and assumes hydrocarbon production is coming from the near-wellbore region. This serves as a baseline to be used throughout the project. As the project continues, the component analysis is applied to each wellbore in the project for several weeks and compared to each well's baseline. Using analytical techniques such as regression analysis the results of later time samples are compared to the early time results to calculate how much hydrocarbon a well is producing from its baseline compared to the other wells in different reservoirs nearby. These results are reported to the engineer on a continuous basis and correlated with other field data to understand the effects of field operations in real time. These data are then applied to future well designs and production strategies and allow for continuous optimization of the reservoir and overall resource recovery.

[026] Tracer and geochemical data sets are valuable to the reservoir model when combined. A group of wells with interwell tracer communication will have varying degrees hydrocarbon component communication over time. Tracer communication is typically observed first followed by communication from light hydrocarbons then followed communication from heavier hydrocarbons. The speed and direction of these trends coupled with well production allows engineers to effectively tune their reservoir model in a development area. This enables optimum reservoir performance and ultimately the asset's performance.

[027] The use of a platform combining geochemical and tracer data for the oil, water and gas phases of production fluids allow engineers to measure reservoir performance in real time and understand how changes made, either at the surface or downhole, impact a producing set of assets. Data taken continuously over several months or years can be used to train reservoir models and improve production forecasting and booking of reserves. These combined data streams that were once snapshots, that is, specific instants in time, and sporadic, can now be integrated together with production data to assemble a complete and continuous picture of what is happening with the reservoir and what impact other wells or operational activities have on the system.

[028] The diagnostic platform is a mobile system with up to six instruments assembled in an enclosed trailer. It is located at the wellsite and directly connected to the production fluids of several wells, typically ten or less. The enclosed trailer will contain insulation, a heating/cooling system, operational fluids, and gases necessary to run the instruments, a battery backup system configured with a network card, and a communications system to transfer the raw data onto a cloud server. A schematic of the diagnostic platform is shown in Figure 3.

[029] The enclosed trailer is approximately 6'x 10'x 6' and is insulated with foam wallboard that is 1" thick or sprayed with polyurethane foam that is ¾" to 1 ½" thick. The heating/cooling system is a single-room portable air conditioner and heater and is approximately 17" x 13" x 27". The communications system is a satellite system such as a Starlink or a cellular router with a boosting antenna of size 12" x 3" x 4". The heating/cooling system can be purchased from Lowes or Home Depot as well as the insulation. The cellular router and antenna can be purchased from any industrial

communications equipment distributor. Starlink can be purchased from SpaceX. The enclosed trailer can be purchased from any of the hundreds of trailer manufacturers. The battery backup system can be purchased from APC of West Kingston, Rhode Island. An equipment rack that contains up to six instruments is used for analyzing the production streams for tracer concentrations, water, or hydrocarbon components. Each instrument will be connected to the production fluid which it is meant to analyze. The trailer containing the instruments will be spotted as close as possible to the production equipment on the wellsite and powered by utility power, a generator, or a light tower. A three-phase well, one that produces oil, natural gas, and water, has a three-phase separator. As the comingled oil, gas and water is produced from the reservoir it flows up the wellbore, through the wellhead, through a flowline and into the three-phase separator. The separator will separate the comingled fluid into oil, gas, and water streams. A small line from each stream will be connected to the instruments. Since there are three main streams, oil, water, and gas, and up to six instruments, the small line from each stream will need to split into two small lines for a total of six small lines, two for gas, two for water and two for oil. The small lines can be 1/16", 1/8" stainless steel, or 1/8" PEX or PEEK. These materials can be purchased from Grainger of Lake Forest, Illinois.

[030] To analyze natural gas components, such as methane, ethane, propane, iso-propane, butane, or iso-butane a gas chromatograph with a flame ionization detector or thermal conductivity detector can be used. To analyze gas tracers dissolved in the natural gas, a gas chromatograph with a mass spectrometer or electron capture detector can be used. General details, methods, and related apparatus may be obtained in United States Patent Application Serial Number 18/108,303 filed February 10, 2023 and published as United States Patent Application Publication Number 2023/0296018 entitled, Continuous Characterization and Communication of Chemical Tracer, which is incorporated by reference herein in its entirety.

[031] To analyze oil components, such as hexanes, heptanes, octanes, decanes, eicosanes or heavier, a gas chromatograph with a flame ionization detector or mass spectrometer can be used. To analyze for oil tracer dissolved in the oil, a gas chromatograph with a mass spectrometer or electron capture detector can be used.

[032] To analyze for anions or cations in the produced water, a liquid chromatograph with a UV-VIS or mass spectrometer detector can be used. To analyze for water tracers dissolved in the produced water, a liquid chromatograph with a UV-VIS or mass spectrometer detector can be used.

[033] In some embodiments fluorinated benzoates, such as sodium 2-fluorobenzoate, sodium 3-fluorobenzoate, sodium 2-(trifluoromethyl)benzoate, and the like, are used as water tracers. These compounds are readily available, stable in the reservoir, easily detectable, and highly water soluble. In some embodiments naphthalene sulfonic acids, such as 1-naphthalene sulfonate, 2-naphthalene sulfonate, 1,5-naphthalene disulfonate, 1,6-naphthalene disulfonate, 2,6-naphthalene disulfonate, and the like are used as water tracers. Pumped with the stimulation treatment the tracers stay dissolved in the stimulation fluid and travel into the formation. Once in the reservoir any formation water contacted by the stimulation treatment will mix with the stimulation fluid. The tracer will stay dissolved in this mixture until they are produced up the wellbore. The tracers are often detected in produced water for several months at concentrations in the parts per billion.

[034] In some embodiments formation water was formed millions of years ago with organic content and water. Formation water can contain salts, minerals and other solids. The layers of subterranean rock were pressurized and cooked resulting in different compositions. Formation water can have high or low salt contents, high or low mineral contents or high or low solids concentrations.

[035] In some embodiments the cations being produced from the subterranean formation are measured and quantified. These dissolved salts, sodium, magnesium, calcium, potassium serve as markers for a reservoir and its water content. By measuring the salt content in real time over several months well operators can determine how the formation is producing and if it is comingling with our formations connected from the stimulation treatment. From initial startup of a well the salt content of the produced water is low as the stimulation fluids are being recovered. Once the stimulation fluids begin to decline cation concentrations increase then plateau and at the native formation water concentration.

[036] In some embodiments water tracer concentrations and cation concentrations are inversely proportional. When a well is on initial flowback its tracer concentrations are high since it hasn't produced back the tracer mass injected into it. If fresh water was used as a

stimulation fluid, cation concentrations will be low since the well is producing its stimulation fluid. Over time tracer concentrations begin to drop and more and more mass of the tracer is produced. Cation concentrations increase as a result of stimulation fluid production declining and formation water increasing since formation water typically contains high cation concentrations. This inverse relationship is a useful diagnostic in determining when a part of the wellbore is producing larger amounts of formation water. Figure 4 shows the inverse relationship of tracer concentrations vs cation concentration. Figure 5 shows a part of the well that is producing more formation water than the other segments over several months since the cation concentrations are high and the tracer concentration is low.

- [037] All of the platform instruments and their consumables can be purchased from Agilent of Santa Clara, California, Thermo Fisher Scientific of Waltham, Massachusetts, Shimadzu of Kyoto, Japan, or Metrohm of Riverview, Florida.
- [038] For operations with multiple wells, each instrument is equipped with a multiport valve. Each multiport valve will have several inlets and one outlet. The valve is electronically actuated and rotates to allow fluids to flow from the desired well. A multiport valve with a dead-end configuration can be used for the gas phase analysis. A multiport valve with a flow-through configuration can be used for water and oil analysis. Either multiport valve configuration can be purchased from Agilent of Santa Clara, California.
- [039] The multiport valve has multiple inputs and one output. By closing off all the inputs but one, known as a dead-end configuration, then cycling to the next input, multiple flow streams can be sampled with one instrument. Figures 6A and 6B show the flow paths of an eight-input multiport valve. In Figure 6A, the fluids are coming into input 1 and exiting through the output at the center of the valve. Inputs 2-8 remain closed to flow, i.e. are dead-end. In Figure 6B, the valve has switched to connect input 2 while closing inputs 3-8 and 1. In some embodiments it is advantageous to use a flow-through valve configuration. Figures 7A and 7B show the flow paths of the flow-through valve where the fluids coming into input 1 exit through the center and flow to the instrument. Unlike the dead-end configuration, inputs 2-8 remain open to flow and, in some embodiments, are

vented. For liquid sample lines such as water or oil a flow-through configuration is necessary to maintain flow through the sample lines.

[040] A diagnostic platform schematic with two wells is shown in Figure 8. Well 1 and Well 2 each have three flow streams, oil, water, and gas. The outlet of each multiport valve is connected to the inlet of each instrument. When sampling begins, each instrument will analyze a sample from Well 1, then the multiport valve on the instrument will switch to Well 2 and analyze a sample. Each instrument in the diagnostic platform is set up to run its own sampling sequence. The sampling sequence consists of analysis time and flushing time. Flushing time is critical to ensure the sample lines from wells being sampled are fresh before each run. The run times for the instruments can vary from two minutes up to one hour.

[041] Each instrument in the platform is controlled by the computer. It executes three major processes: operation of the instrument, quantification of the tracers and transmission of the data. The computer tells the multiplexing valve when to open and rotate, and when to activate the injection system. It quantifies the raw data from the system into time, date and concentration of the tracer or geochemical components. It then prepares the data to be sent over-the-air via the communications system. The communications system takes the data in packets, encrypts them and transmits them via the internet to a receiving cloud computer or computer network.

[042] The production fluids travel through the reservoir, then the wellbore, the separator, the sample lines, into each instrument, through its internal parts, and out its outlet where the production fluids will be reintroduced into the production equipment or collected for waste. Each instrument produces a chromatogram, a time v. intensity plot, where the analytes appear as peaks. Each analyte is a different component or tracer chemical, and the area of its peak is proportional to its concentration. Once the instrument has completed its analysis, the time v. intensity data of the chromatogram will be transferred to a cloud repository. These files will be uploaded to a time v. intensity plot for each sample and quality controlled by a data analyst. This is done for every sample each instrument analyzes. The flow path of the reservoir fluid, the separation and the analysis, data processing, and results can be seen in Figure 9.

[043] The last part of the diagnostic platform is the data delivery system which consists of time, date, and concentration outputs of the tracers or geochemical data from the instrument as well as well diagrams, field diagrams, formation diagrams, flowback schedules, production data, pressure data, and flowback data. The system together enables engineers to make decisions and changes to their operations in real time and validates whether their changes are effective.

[044] Before the availability of the diagnostic platform, well samples had to be collected at the wellsite, transported from the field, shipped to a lab via a courier, analyzed in the lab and processed into a data report. This process takes weeks, is sporadic, and has results for only an instant in time. Automated continuous data streams are not only easier to obtain but also provide much greater detail as to the performance of the reservoir.

[045] Figures 10, 11, and 12 show continuous reservoir data from the same well and time horizon for water tracer and water cation analysis, oil tracer and oil component analysis, and gas tracer and gas component analysis. Each of these figures comprises thousands of data points in the same time horizon.

[046] Each component of the diagnostic platform is essential for continuously monitoring and optimizing reservoir performance. The enclosed trailer, insulation, and heating and cooling system allows the instruments to be placed at field locations that are remote with harsh ambient conditions. The satellite or cellular communication systems allows for transferring of large amounts of instrument data and continuous monitoring of the platform function. The instruments analyze the fluids for specific components used to monitor the reservoir. The sample lines carry the production fluids to the instrument, through the injection system and back to the production system or waste stream. The multiport valves allow the system to switch between multiple wells as directed by the sampling sequence. Power to the diagnostic platform keeps its components running on a continuous basis. The data delivery system summarizes the vast amount of data the platform produces into actionable data sets that engineers can use to optimize reservoir production.

Case Study

[047] A well operator ran the diagnostic platform to diagnose production from a section of a horizontal well that was drilled out of zone. The horizontal well was three miles long in length and the toe portion of the lateral was drilled into rock above the intended target.

Three unique water and three unique gas tracers were injected into segments one mile long during fracturing stimulation. After the well was completed and put on production the diagnostic platform was spotted ten feet from the separator and connected to the water, oil and gas lines. The platform was powered with utility power from the wellsite's production facility. Five instruments were used to monitor production fluids, a gas chromatograph with an electron-capture detector for gas tracers, a gas chromatograph with a thermal conductivity detector for gas components, a liquid chromatograph with a UV-VIS detector for water tracers and cations and a gas chromatograph with a flame-ionization detector for oil components.

[048] A multiport valve in the dead-end configuration was used for the gas-chromatograph electron-capture detector for the gas tracers. It was connected to the well and a check sample. Analysis times were fourteen minutes with a twenty-minute flush time. A multiport valve in the flow through configuration was used for the gas chromatograph thermal conductivity detector for the gas components, the liquid chromatograph UV-VIS for the water tracers and cations and the gas chromatograph flame ionization detector for the oil components. The analysis time for the water tracers was twenty minutes with a five-minute flush time. The analysis time for the water cations was twelve minutes with a five-minute flush time. The analysis time for the gas components was five minutes with a five-minute flush time and the analysis time for the oil components was sixty minutes with a twenty-minute flush time.

[049] Each instrument's sampling sequence was activated and the data from each instrument was transferred to a cloud computer each morning via the internet connection and processed for delivery to the customer. Data was delivered using summary visualization chart each morning. The diagnostic platform was run for thirty days automatically with no issue.

[050] Initial diagnostic platform data from the well's production indicated a blockage in the first mile of the lateral near the toe portion. Both the gas and water tracer data showed lagging concentrations from the tracers pumped in the toe section. Initial cation concentrations indicated that the well was recovering its freshwater stimulation fluid as normal. Initial natural gas components indicated lower btu gas and corresponding higher

methane concentrations than the well operator expected. Initial oil components were producing as expected.

[051] To alleviate the blockage in the toe portion of the lateral the engineering team surged the well to dislodge the debris partially constraining production. The operation worked and water and gas tracer concentrations of the toe portion of the lateral increased and began to trend in a similar way to the other tracers. Several days after the blockage was cleared the natural gas and oil components began to show heavier hydrocarbon profiles. This response suggested that the toe portion of the lateral had heavier hydrocarbons in place and once it started contributing to production changed the overall profile. The cation concentrations began to trend upward further into production which was normal and expected. The cation concentrations for the project were comparable to other projects in the area and did not suggest that the well had encountered any significant produced water zones.

[052] This diagnostic platform dataset was used to evaluate the landing targets for the reservoir as well as operating procedures for clean outs after completion operations. Since the data was taken in real time from five components the engineering team was able to quickly apply their learnings to the next set of wells being completed. This was not possible before the diagnostic platform.

[053] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

[054] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[055] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as “open” terms (for example, the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at least,” the term “includes” should be interpreted as “includes but is not limited to,” et cetera). While various compositions, methods, and devices are described in terms of “comprising” various components or steps (interpreted as meaning “including, but not limited to”), the compositions, methods, and devices can also “consist essentially of” or “consist of” the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present.

[056] For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases “at least one” and “one or more” to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an” (for example, “a” and/or “an” should be interpreted to mean “at least one” or “one or more”); the same holds true for the use of definite articles used to introduce claim recitations.

[057] In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of “two recitations,” without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to “at least one of A, B, and

C, et cetera” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, “a system having at least one of A, B, and C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to “at least one of A, B, or C, et cetera” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, “a system having at least one of A, B, or C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase “A or B” will be understood to include the possibilities of “A” or “B” or “A and B.”

[058] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[059] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera. As will also be understood by one skilled in the art all language such as “up to,” “at least,” and the like include the number recited and refer to ranges that can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 devices refers to groups having 1, 2, or 3 devices. Similarly, a group having 1-5 devices refers to groups having 1, 2, 3, 4, or 5 devices, and so forth.

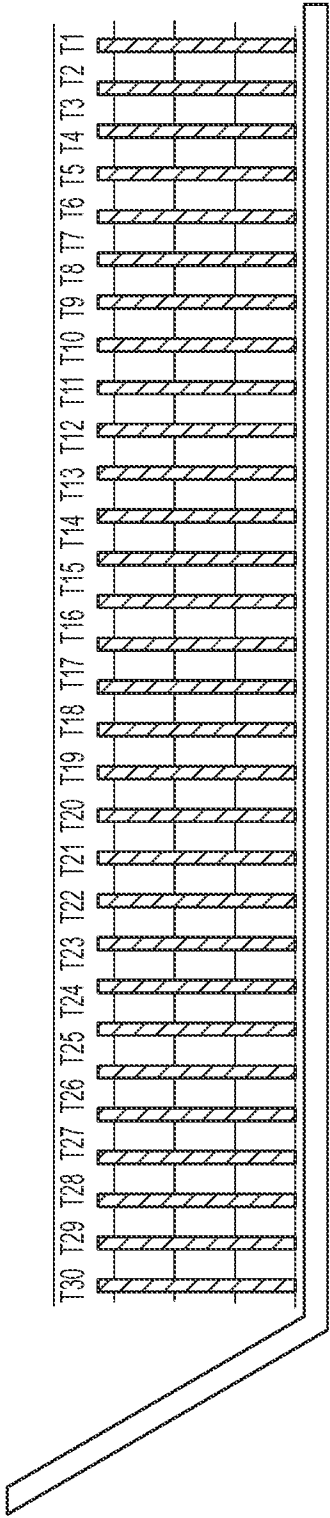
[060] Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

Claims

We claim:

1. A method to observe a sample from a wellbore traversing a subterranean formation, comprising:
continuously collecting a sample from the wellbore, wherein the collecting comprises a separator and a valve;
observing the sample in an instrument for characterizing the sample, wherein the instrument is enclosed in a housing;
reporting a result of the observing; and
controlling the temperature of the housing, instrument, sample, valve, or a combination thereof.
2. The method of claim 1, wherein the valve comprises a multiport valve.
3. The method of claim 2, wherein the multiport valve has a flow through configuration.
4. The method of claim 2, wherein the multiport valve has eight ports.
5. The method of claim 2, wherein the multiport valve accepts samples from two wellbores.
6. The method of claim 1, wherein the instrument comprises a mass spectrometer with electron capture, flame ionization with thermal conductivity, flame ionization with mass spectrometer, mass spectrometer with UV-Vis, or a combination thereof.
7. The method of claim 1, wherein the reporting comprises a satellite system, a cellular router, a controller, or a combination thereof.
8. The method of claim 1, wherein the reporting occurs once every twenty-four hours.
9. The method of claim 1, wherein the reporting comprises results from two or more instruments.
10. The method of claim 9, wherein the reporting comprises results from two or more instruments within the same hour.
11. The method of claim 1, wherein the housing comprises a heating and cooling unit, a power supply, a water reservoir, operation gas, calibration gas, a sample outlet, or a combination thereof.
12. The method of claim 1, wherein the separator separates the sample into gas, oil, water, or a combination thereof.

13. The method of claim 1, wherein the continuously collecting a sample further comprises continuously flowing a portion of the sample through a port of the valve.
14. An apparatus to observe a sample from a wellbore traversing a subterranean formation, comprising:
 - a sample continuously collected from the wellbore, wherein the sample flows through a separator and a valve;
 - an instrument that characterizes the sample and records results of the characterizing, wherein the instrument is enclosed in a housing;
 - a controller that controls the temperature of the housing; and
 - a reporting device comprising a satellite system or a cellular router.
15. The apparatus of claim 14, wherein the valve comprises a multiport valve.
16. The apparatus of claim 14, wherein the multiport valve has eight ports.
17. The apparatus of claim 14, wherein the instrument comprises a mass spectrometer with electron capture, flame ionization with thermal conductivity, flame ionization with mass spectrometer, mass spectrometer with UV-Vis, or a combination thereof.
18. The apparatus of claim 14, wherein the reporting device captures results from two or more instruments.
19. The apparatus of claim 14, wherein the capturing comprises results from two or more instruments within the same hour.
20. The apparatus of claim 14, wherein the housing comprises a heating and cooling unit, a power supply, a water reservoir, operation gas, calibration gas, a sample outlet, or a combination thereof.



Balanced Flow Profile

FIG. 1

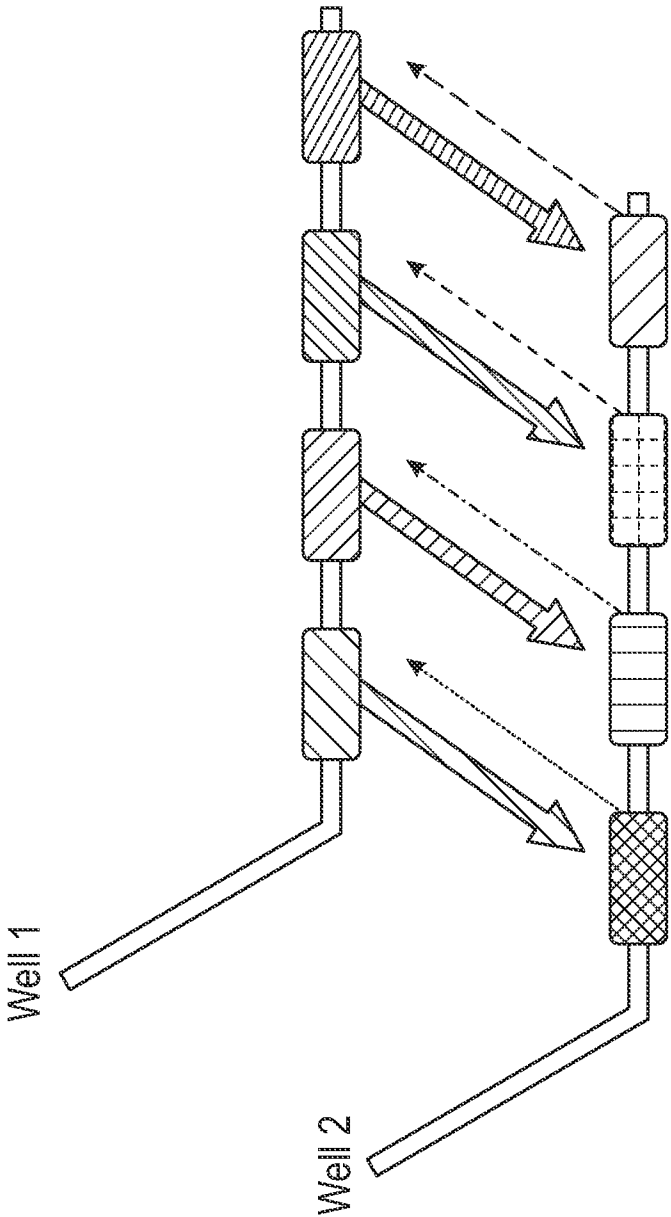


FIG. 2

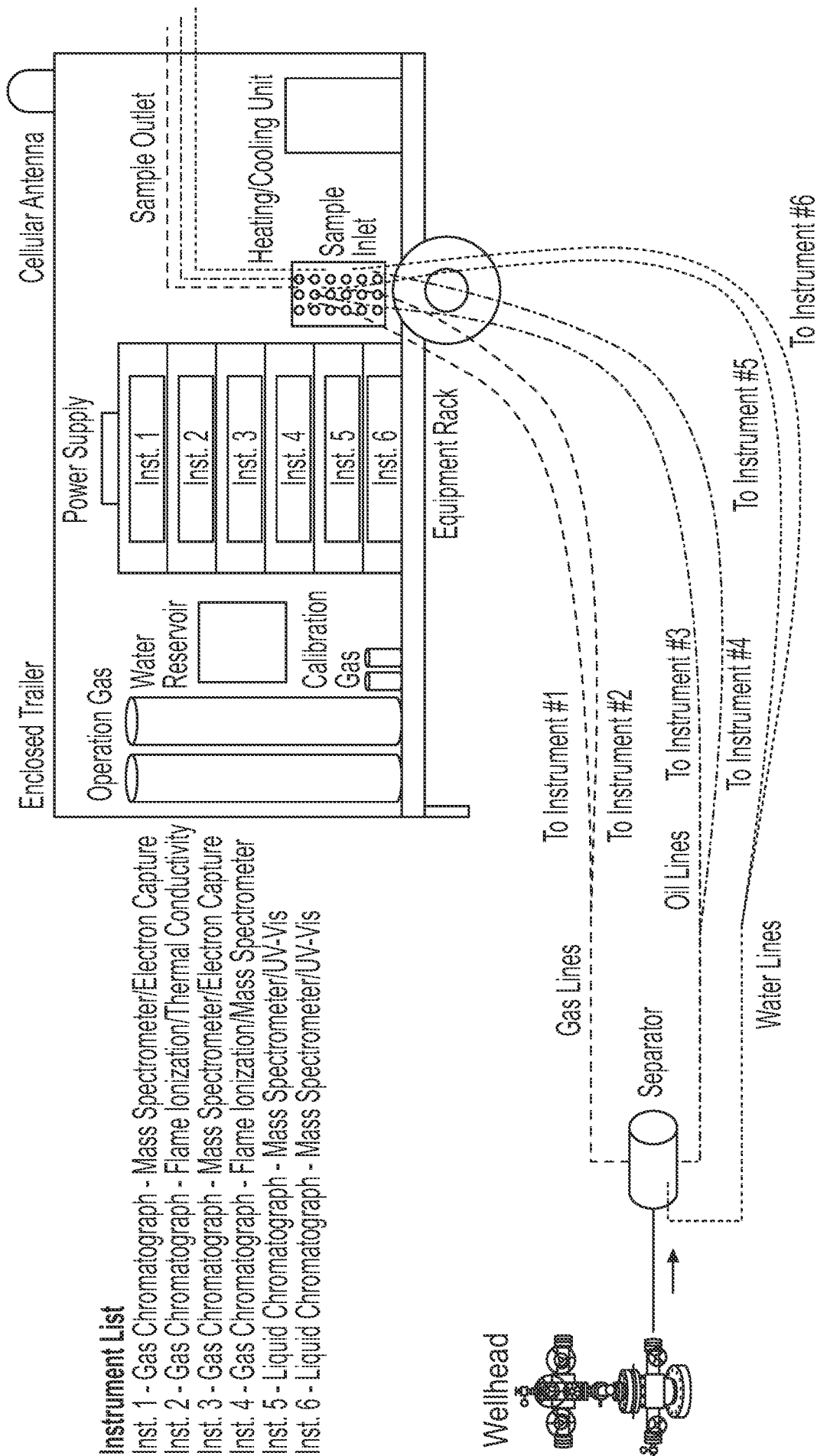
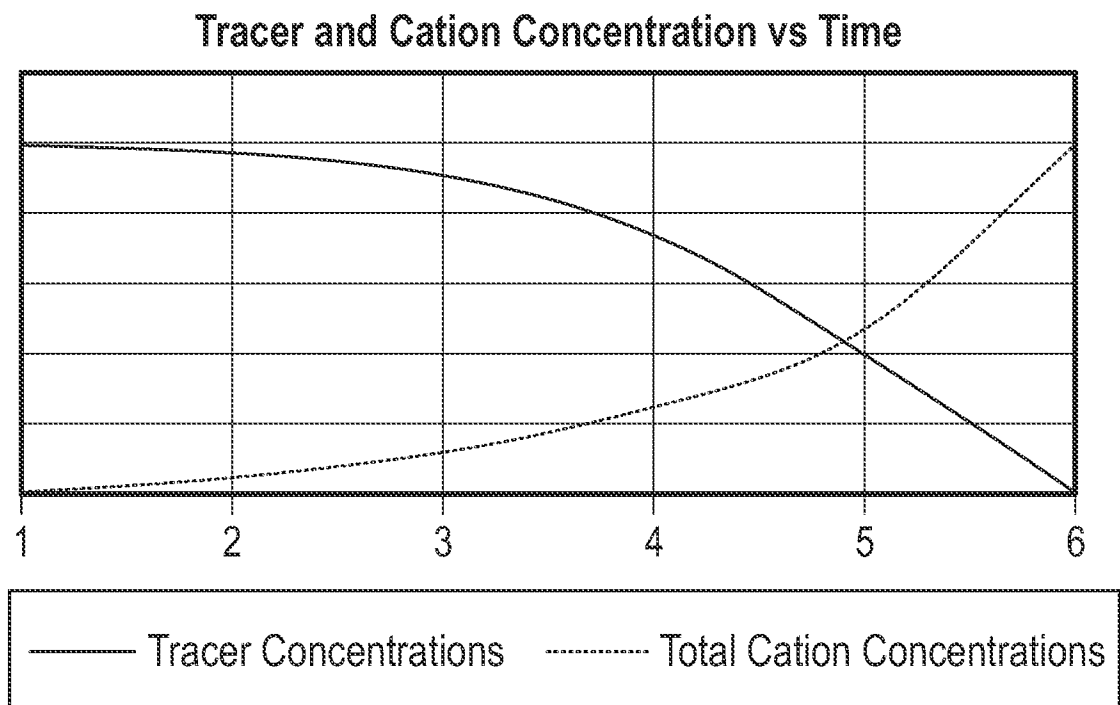
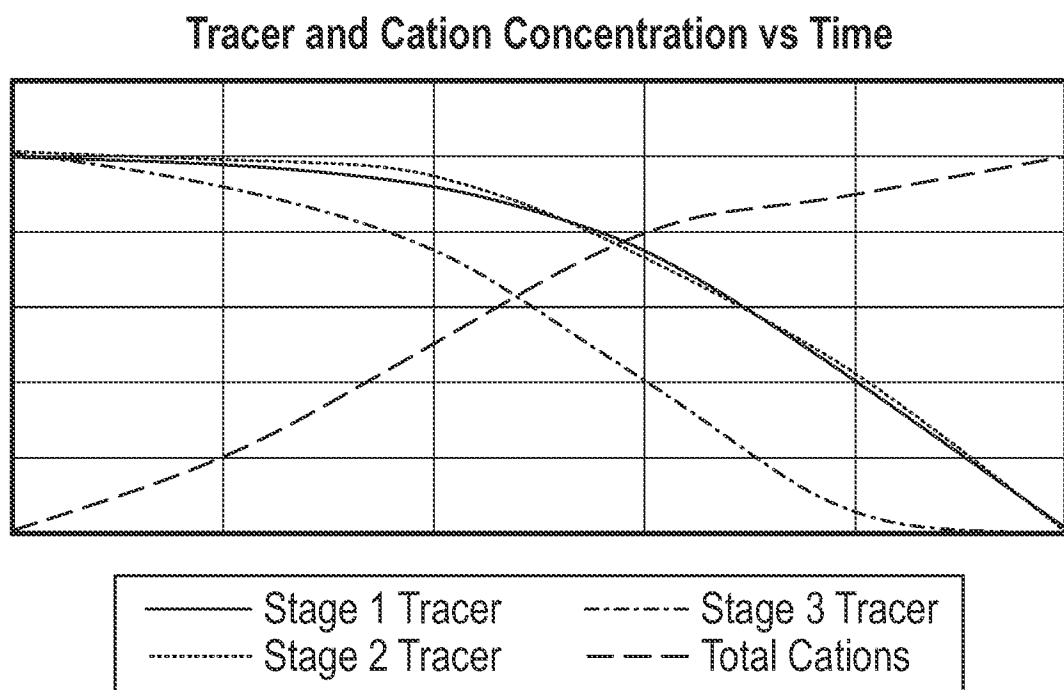


FIG. 3

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**FIG. 4****FIG. 5**

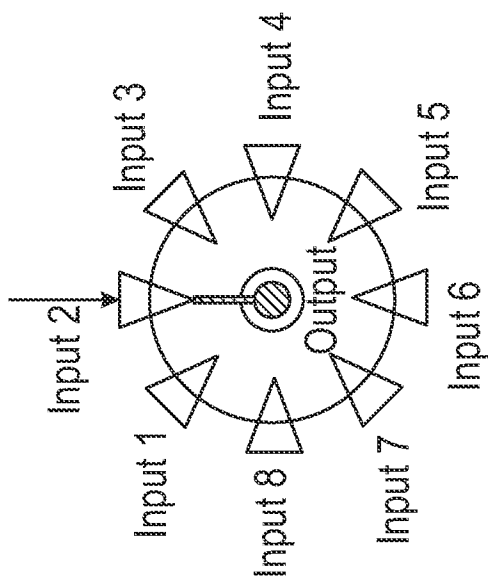


FIG. 6A

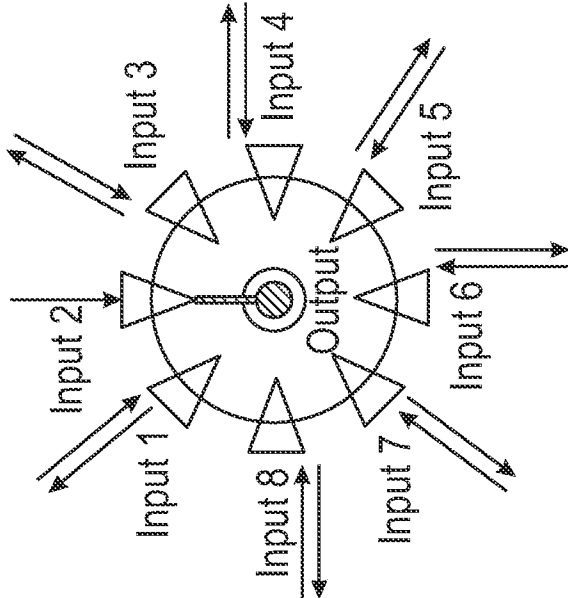


FIG. 6B

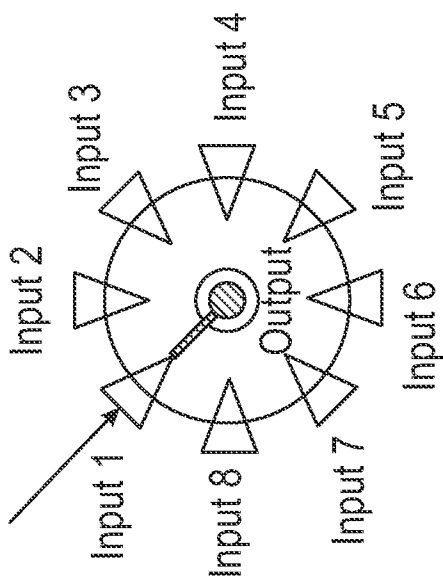


FIG. 7A

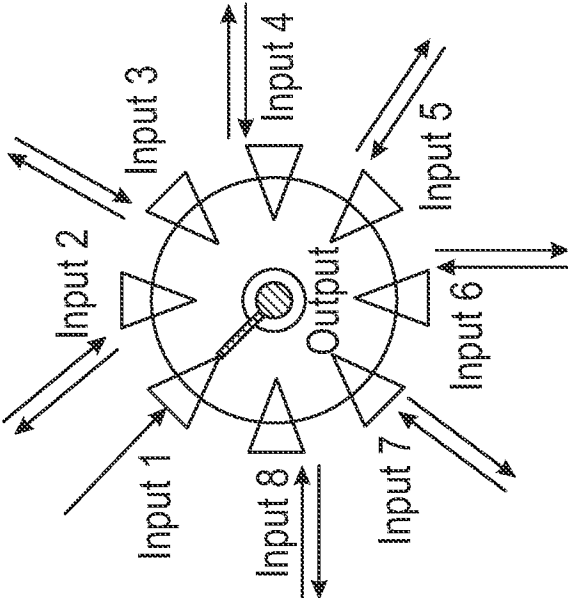


FIG. 7B

- Instrument List**
- Inst. 1 - Gas Chromatograph - Mass Spectrometer/Electron Capture
 - Inst. 2 - Gas Chromatograph - Flame Ionization/Thermal Conductivity
 - Inst. 3 - Gas Chromatograph - Mass Spectrometer/Electron Capture
 - Inst. 4 - Gas Chromatograph - Flame Ionization/Mass Spectrometer
 - Inst. 5 - Liquid Chromatograph - Mass Spectrometer/UV-Vis
 - Inst. 6 - Liquid Chromatograph - Mass Spectrometer/UV-Vis

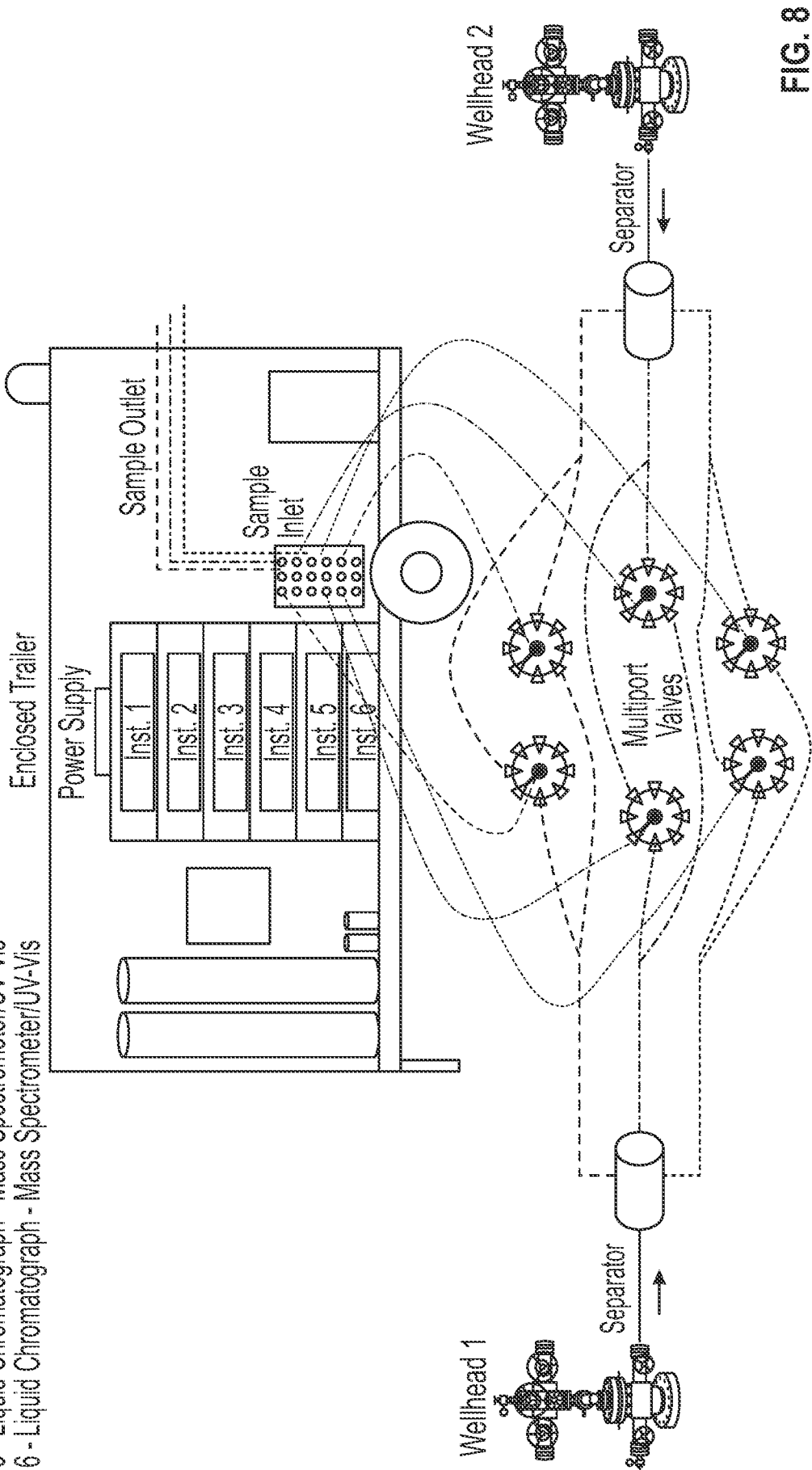


FIG. 8

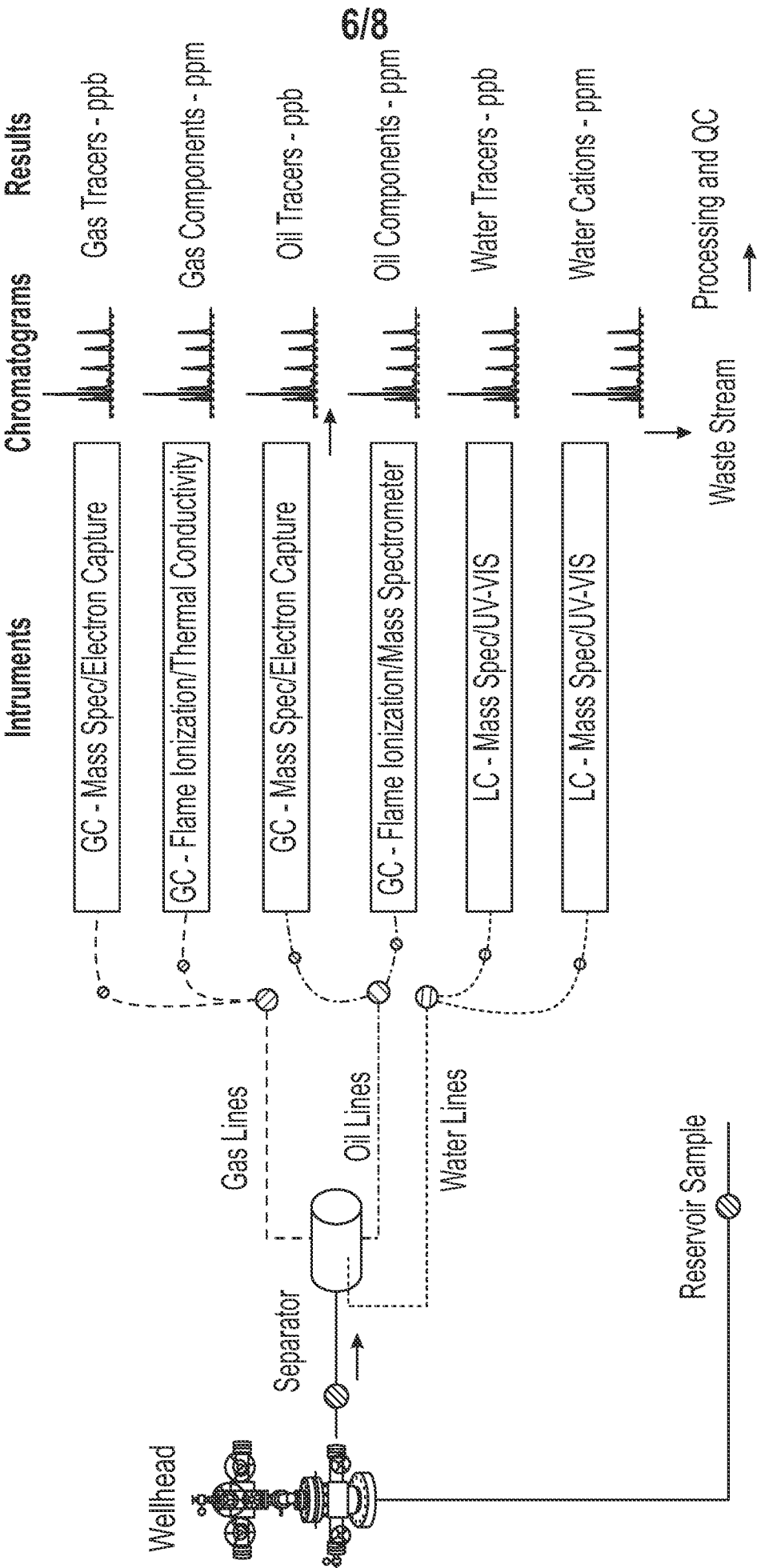
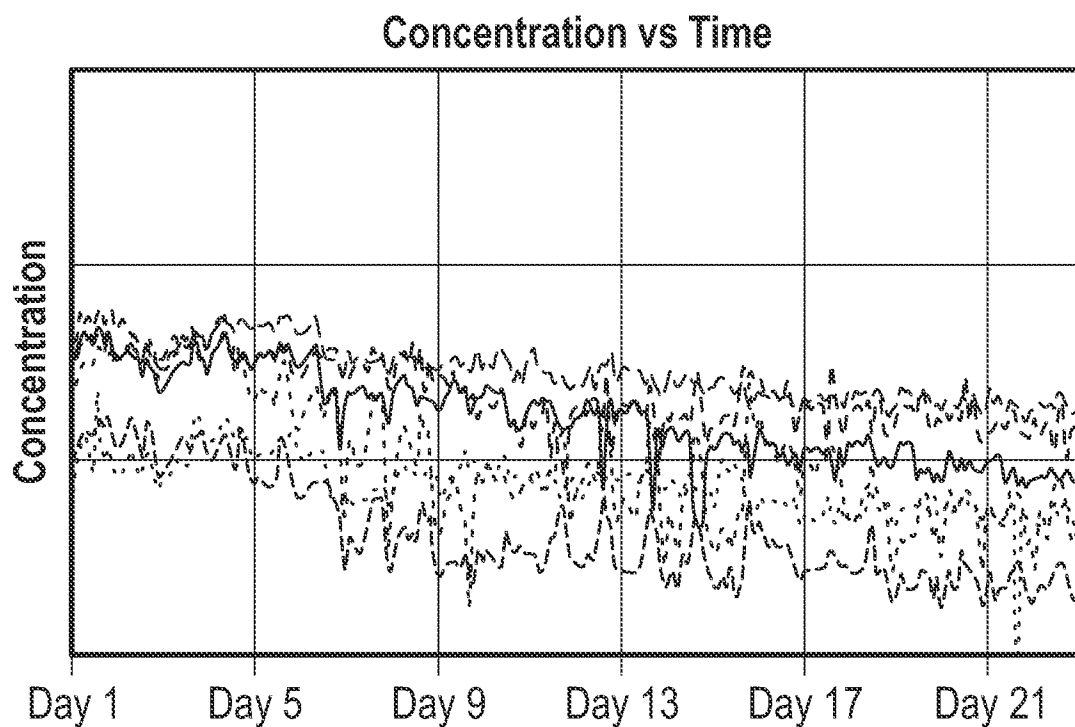
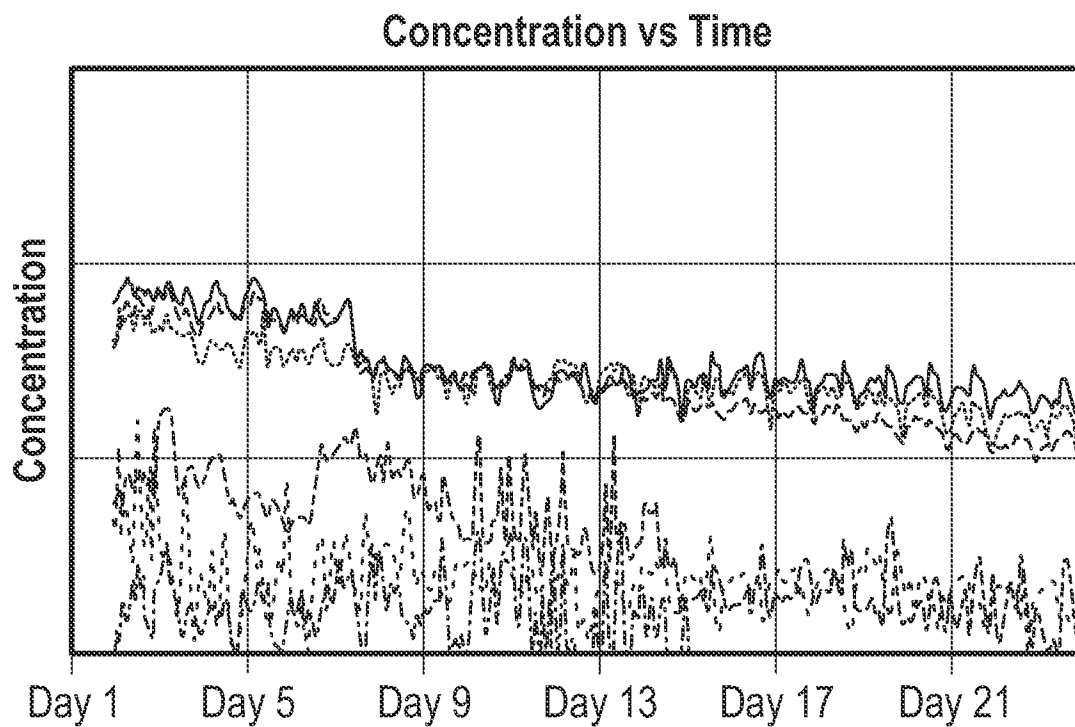
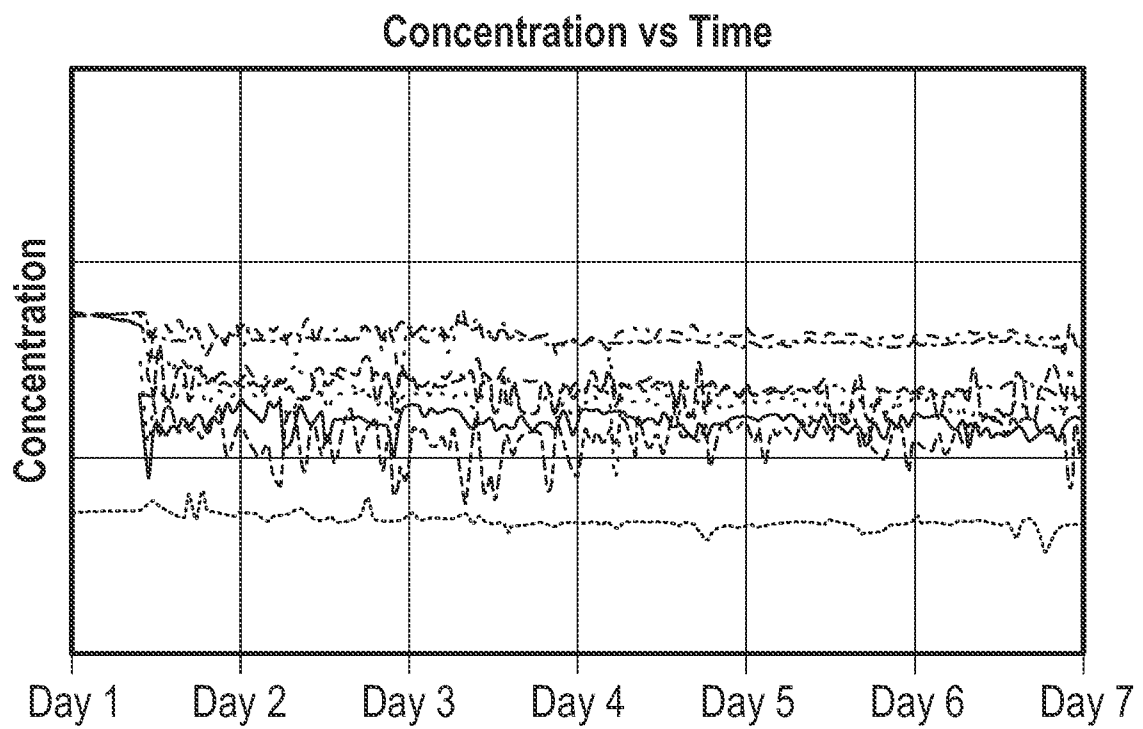


FIG. 9

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**FIG. 12**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/033495

A. CLASSIFICATION OF SUBJECT MATTER E21B 49/08(2006.01)i; E21B 36/00(2006.01)i; E21B 34/02(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) E21B 49/08(2006.01); E21B 43/34(2006.01); E21B 49/00(2006.01); G01F 1/34(2006.01); G01F 1/66(2006.01); G01F 3/00(2006.01); G01N 33/28(2006.01) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & Keywords: wellbore, sample, separator, multiport valve, temperature, mass spectrometer, satellite system		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010-0132449 A1 (BIRKETT et al.) 03 June 2010 (2010-06-03) paragraphs [0017], [0029], [0031], [0032], [0046], claims 1, 7, and figures 1-8	1-20
Y	CN 203455035 U (CHINA NATIONAL PETROLEUM CORPORATION et al.) 26 February 2014 (2014-02-26) paragraph [0013] and figures 1, 2	1-20
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A	US 2011-0153225 A1 (LARS NICOLAS MANGAL et al.) 23 June 2011 (2011-06-23) paragraph [0047] and figure 5	1-20
A	WO 2020-139348 A1 (HALLIBURTON ENERGY SERVICES, INC.) 02 July 2020 (2020-07-02) claim 1	1-20
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family		
Date of the actual completion of the international search 30 September 2024		Date of mailing of the international search report 30 September 2024
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer PARK, Tae Wook Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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