

SAMPLE CAPTURE SYSTEM AND METHODS OF USE**Technical Field**

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The present disclosure relates to a sampling system.

Background

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Sampling methods and devices have been employed in numerous industries to monitor the instantaneous composition of gaseous, liquid and/or multi-phase fluid streams at specified locations of a reaction system. Sampling methods typically involve withdrawing a small sample from a bulk stream or sampling environment, in order to analyze the composition of specific analyte compounds present in the sample. Results of such analysis can serve numerous purposes, such as limits testing, monitoring rates of reaction, extent of reaction, testing for toxicity limits and detecting presence of hazardous compounds.

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One commonly employed sampling device is the six-port valve, whereby fluid is drawn from one inlet and may be suitably channeled to at least five other outlets. The control of fluid flow is through a flow selector, typically a ball valve. The drawback with the six-port valve is that it is unsuited for operating under high pressures. This can be problematic when the sampling environment is highly pressurized, which is common in, e.g., hydrocarbon processing units such as hydrocrackers. The high pressure of the sampling environment can lead to damage of the sampling device and in worse cases, lead to the leakage of the sample, which may contain toxic substances harmful to personnel collecting the sample.

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Furthermore, sampling devices like the six-port valve make use of ultra-narrow tubing which can be less than 1/16th inch (15.875 mm) in diameter. Such devices are unsuited for use in sampling environments that contain
5 considerable quantities of impurities and particulates due to the fact that the narrow tubing is highly prone to clogging by the particulate matter in the sampled stream, for example, a raw hydrocarbon stream.

Rotary valves have also been used for conventional
10 sampling. A rotary valve typically consists of a series of inter-connectable internal passages to define at least two alternate valve positions, for example, "sampling position" wherein a sample is collected or a "bypass position" where no sample is collected. These internal passages are usually
15 made of hair-line tubing and are advantageously suited for gas sampling. However, these hairline tubings are prone to blockage by particulate matter especially when the sampling fluid contains both liquid and gaseous matter. Furthermore, the hairline tubings lack physical strength and may
20 collapse after repeated cycles of sampling either due to clogging or pressure damage. As a result, where rotary valves have been employed, there is usually a need to install upstream filters to remove small particulate matter from the withdrawn sample to avoid clogging up the rotary
25 valve. This adds to overall operating costs and is not desired.

Pneumatic cell-type sampling devices have been proposed that are capable of handling high pressure liquid systems. However, a significant drawback with known cell-
30 type sampling devices is that the withdrawn samples may not be well-mixed and homogeneous and therefore fail to capture all the analyte in the sample. In this respect, it is known

that some chemical analytes present in a bulk sampling stream can be volatile and exist in partial gaseous and liquid phases. As such, a representative sample is often difficult to acquire as the analyte partitions between the vapor and liquid phase. Consequently, the analysis results may be unable to measure an accurate composition of a non-homogeneous sample.

Another sampling device has also been proposed, which includes a mixer component for mixing and homogenizing the withdrawn sample prior to analysis. However, such a device is only capable of sampling in batch-mode and cannot be used in a continuous sampling mode.

Furthermore, when fluid samples are withdrawn from the sampling environment, the samples may experience a drop in pressure. This drop in pressure may result in flashing of one or more compounds present within the sample, causing the formation of a multiphase fluid. As such, some analytes may exist in at least two phases and may not be completely captured in the sample that is eventually sent to an analyzer unit for analysis. In such a case, the analysis results will be unable to provide a representative composition of the sampling environment.

As such, there is a need to provide a sampling system that is capable of at least ameliorating or overcome one or more of the disadvantages above. In particular, there is a need to provide a sampling system that is capable of withdrawing samples from a highly pressurized multiphase, multicomponent sampling environment. There is also need to provide a sampling system that can operate in a continuous mode in order to monitor real time changes in the compositions of the sampling environment. There is further

a need to provide a sampling system that is capable of providing a homogeneous, single phase sample for analysis.

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Summary

In a first aspect, there is provided a sampling system for obtaining a representative fluid sample from a high pressure multiphase multicomponent fluid, the system
10 comprising: a fluid flow path for transmitting the high pressure multiphase multicomponent fluid therethrough, the pressure of the fluid flow path being substantially the same as the pressure of an environment to be sampled; a sample capture chamber in direct fluid communication with
15 the fluid flow path and having an inlet for receiving the high pressure multiphase, multicomponent fluid therein and an outlet for expelling the high pressure multiphase, multicomponent fluid therefrom; valves means configured to fluidly seal the inlet and outlet of said sample capture
20 chamber and thereby capture the representative fluid sample of the high pressure multiphase multicomponent fluid as it passes therethrough; and control means for controlling the valve means so that the pressure of the representative fluid sample is substantially the same as the high pressure
25 multiphase multicomponent fluid in said fluid flow path.

As the representative fluid sample is captured within the sample capture chamber with minimal or no pressure loss, the captured fluid sample does not undergo phase changes during the capturing process. Advantageously, the pressure
30 in the sample capture chamber can be adjusted by controlling the pressure in the fluid flow path. As such, the operator is able to easily control the pressure in the capture sample chamber in accordance with the type and

composition of sample fluid to be captured, in order to acquire a representative sample.

In a preferred embodiment, the pressure in the fluid flow path is above the bubble point pressure of the
5 multiphase multicomponent fluid.

Advantageously, by maintaining the fluid sample above the bubble point pressure at the time the sample is captured, a more accurate representative sample of the fluid may be obtained. For example, if the fluid is a
10 mixture of hydrocarbons from a natural gas field at high pressure, part of the fluid will be in a liquid phase and part of the fluid will be in a gas phase. By capturing the fluid above the bubble point, and more typically at the high pressure that corresponds to the area of the natural
15 gas processing facility being sampled, a more accurate representative sample can be obtained. The multicomponent fluid sample may be captured as a single phase sample, such as a single phase liquid sample. Advantageously, this enables all of the components in the sample to be captured
20 in a single phase, which then allows for an accurate analysis of the sample's composition subsequently. This is particularly important for upstream natural gas and oil extraction facilities as it is important for the operators of these plants to have an accurate sample of what is being
25 processed upstream. In particular, obtaining an accurate upstream sample allows plant operators to adjust their processes downstream or to provide an accurate compositional analysis to their customers who purchase the natural gas or oil.

30 In a second aspect, there is provided a method for obtaining a representative fluid sample from a high pressure multiphase, multicomponent fluid, the method

comprising the steps of: (a) providing a fluid flow path for transmitting the high pressure multiphase multicomponent fluid therethrough; (b) providing a sample capture chamber in direct fluid communication with the fluid flow path and having an inlet for receiving the high pressure multiphase multicomponent fluid therein and an outlet for expelling the high pressure multiphase multicomponent fluid therefrom; (c) fluidly sealing the inlet and outlet of said sample capture chamber with a valve means and capturing the representative fluid sample from the high pressure multiphase multicomponent fluid as it passes through the sample capture chamber; and (d) controlling the valve means so that the pressure of the representative fluid sample is substantially the same as the high pressure multiphase multicomponent fluid in the fluid flow path.

In another aspect, there is provided a sampling device comprising: (a) a housing having an internal conduit that extends through said housing to define a liquid flow path from an inlet for receiving a liquid from a sampling environment to an outlet that discharges said liquid from said housing; (b) a sample capture chamber in fluid communication with said liquid flow path for capture of a liquid sample as said liquid flows along said flow path; and a valve means for transmitting said liquid from said inlet along said flow path to said outlet, and being configured to intermittently direct said liquid to said sample capture chamber to obtain the liquid sample.

The fluid flow path of the above device may be shaped to substantially homogenously mix the liquid sample as it flows therethrough. In one embodiment, the internal conduit may comprise a plurality of bends that are disposed

along the fluid flow path for inducing turbulent fluid flow of the liquid flowing through. In another embodiment, the internal surface of the conduit may comprise a plurality of groove formations that induce or promote turbulent fluid
5 flow of the liquid flowing through.

The valve means of the above device may be configured to intermittently isolate said capture chamber and thereby capture a liquid sample therein. The valve means may further be configured to release the isolated liquid sample
10 to a sample release conduit.

The above device may further comprise a sensor configured to detect at least one chemical or physical property of said liquid sample. The chemical property detected by the sensor may relate to the composition of the
15 liquid sample; whereas the physical property detected by said sensor may relate to a property selected from the group consisting of viscosity, temperature and pressure.

The housing of the disclosed device may be a pressure vessel capable of operating at pressures above atmospheric
20 pressure. The pressure vessel housing may be capable of operating at pressures pressure of at least 17000 kPa. The housing may further comprise an insulation means to insulate the internal conduit. The internal conduit which defines the liquid flow path may be comprised of a series
25 of manifolds that are in fluid communication with each other.

In one embodiment, the housing may comprise a molded modular block having the internal conduit extending through the molded modular block.

30 The disclosed valve means of the above device may comprise a series of valves selected from isolation valves, shut-off valves, plunger valves, ball valves, and

combinations thereof. In one embodiment, the valve means comprises three-way ball valves.

The device may further comprise a gas inlet in fluid communication with said internal conduit for passage of gas
5 therein. The device may also comprise a solvent inlet in fluid communication with said internal conduit for passage of solvent therein.

The fluid flow of the liquid within the internal conduit may be at generally turbulent fluid flow conditions.

10 In one embodiment, the turbulent fluid flow is at a Reynolds Number of at least 4000.

In yet another aspect, there is provided an in-line sampling system comprising: a liquid stream containing an analyte therein to be sampled; a housing having an internal
15 conduit that extends through said housing to define a liquid flow path from an inlet in fluid communication with said liquid stream to an outlet that discharges said liquid stream from said housing; a sample capture chamber in fluid communication with said liquid flow path for capture of a
20 liquid sample as said liquid stream flows along said flow path; and a valve means for transmitting said liquid stream from said inlet along said flow path to said outlet, and being configured to intermittently direct said liquid stream to said sample capture chamber to obtain the liquid
25 sample.

The housing of the above system may comprise a sample release conduit in fluid communication with the sample capture chamber, wherein the valve means is configured to release the liquid sample to the sample release conduit.

30 The system may further comprise means for analyzing the liquid sample to determine at least one of a chemical or physical characteristic of said liquid sample. In one

embodiment, the means for analyzing may comprise one or more mass spectrometers. The system may further comprise data collection means configured to record data generated by the analyzing means.

5 In the disclosed system, the internal surface of the conduit may be coated with an anti-corrosive agent. In the disclosed system, the liquid sample may be intermittently isolated in the sample capture chamber and discharged into the sample release conduit.

10 The fluid flow in the disclosed system may be turbulent, characterized by a Reynolds of at least 4000 or more.

Definitions

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The following words and terms used herein shall have the meaning indicated:

In the context of the present specification, the term "turbulent flow" is used to broadly refer to a state of fluid flow whereby the Reynolds Number is at least 4000 or greater.

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In the context of this specification, the term 'phase' refers to a type of fluid that can exist in contact with other fluids in a vaporized gaseous state or in a liquid state. A "multi-phase" fluid is a fluid containing more than one phase (i.e., liquid and gas), and can include a fluid having two or more liquid phases and/or a combination of a gas phase with one or more liquid phases. Hence, the term multi-phase is used with reference to a mixture of hydrocarbon liquids, natural gas vapors and water, including a discrete hydrocarbon liquid and a discrete water phase as well as a discrete vapor phase containing water and hydrocarbon gases.

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The term "bubble point pressure" is defined as the pressure at which the first gas bubble appears in a fluid sample while decreasing the pressure on the fluid sample.

The term "high pressure" in the context of this specification refers to any pressure above atmospheric pressure.

The word "substantially" does not exclude "completely" e.g. a composition which is "substantially free" from Y may be completely free from Y. Where necessary, the word "substantially" may be omitted from the definition of the invention. In the context of the specification, the phrase "substantially the same pressure" with respect to a fluid sample means that the pressure as measured with reference to another pressure point, is the same or varies by less than 10%, more preferably less than 5%, and more preferably less than 1%.

Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

As used herein, the term "about", in the context of concentrations of components of the formulations, typically means $\pm 5\%$ of the stated value or higher, more typically $\pm 4\%$ of the stated value, more typically $\pm 3\%$ of the stated value, more typically, $\pm 2\%$ of the stated value, even more typically $\pm 1\%$ of the stated value, and even more typically $\pm 0.5\%$ of the stated value. Although such values can vary, consistency of values is aimed throughout when used in the context of this invention.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that

the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges.

Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Disclosure of Optional Embodiments

Exemplary, non-limiting embodiments of a sampling system will now be disclosed.

The high pressure multiphase multicomponent fluid may contain gaseous and liquid components. Exemplary gaseous components include hydrocarbons such as natural gas, liquefied petroleum gas and non-hydrocarbons such as air and flue gas. Exemplary liquid components include hydrocarbons such as natural gas condensate, crude oil or refined crude oil components such as naptha, kerosene, diesel, etc and non-hydrocarbon components such as water. In a preferred embodiment, the disclosed system is used to acquire a sample of high pressure natural gas condensate.

The disclosed sample capture chamber may have a pre-determined fixed volume once the inlet and outlet have been sealed by the valve means. In one embodiment, this pre-determined volume is sufficiently small to facilitate rapid

analysis, for example, about 1 cm³ or less. However, it should be appreciated that the volume of the sample capture chamber may vary in accordance with the type of fluid that is to be captured and the conditions under which the sample
5 is captured. Accordingly, sample capture chambers with volumes larger than 1 cm³ are also envisioned.

In a preferred embodiment, the pressure in the fluid flow path is above the bubble point pressure of the multiphase multicomponent fluid. After capturing a fluid
10 sample in the sample capture chamber, the valve means may unseal the outlet in order to release the captured fluid sample. The fluid sample may be released or passed to an analyzer means configured to analyze the components of the released sample. The analyzer means may be any suitable
15 mass spectrometer apparatus, such as but not limited to, a liquid chromatogram mass spectrometer, a high pressure liquid chromatogram mass spectrometer, a gas chromatogram mass spectrometer. It is also envisioned one or more processing units, such as a conversion unit, may be
20 installed between the outlet and the analyzer means. Such processing units may be used to convert the sample into an analyzable form suitably catered to the actual analyzer used.

The released sample may experience a drop in pressure,
25 resulting in flashing of one or more compounds present within the sample, causing the formation of a multiphase fluid.

The disclosed control means may be configured to actuate the valve means such that the inlet and the outlet
30 of the sample capture chamber are sealed synchronously. Advantageously, the synchronous sealing allows the sample

fluid to be captured in an efficient manner, reducing pressure loss during the sealing process.

The synchronous sealing of the inlet and outlet of the sample capture chamber may be undertaken within a time frame that is relatively short, in order to maintain the fluid pressure in the sample capture chamber to be substantially the same as the pressure of the fluid flow path. In one embodiment, the synchronous sealing is undertaken in 5 seconds or less, preferably 4 seconds or less, even more preferably, 3 seconds or less.

The disclosed control means may comprise a network of sensors that monitor the pressure at specified locations along the fluid flow path. The control means may further comprise actuators that are operably linked with the sensors and the valve means for fluidly sealing the sample capture chamber. The control means may further comprise a programmable logic controller (PLC) that is electronically coupled to the sensors and valve means. In one embodiment, the PLC is programmed with a pre-determined logic to initiate one or more specified valve switching sequences, once a set of pre-defined pressure set points have been detected by the sensors. In one embodiment, the actuators are selected from pneumatic actuators and stepper motors, which are capable of activating the valve means for sealing the chamber.

The disclosed valve means may be selected from isolation valves, shut-off valves, plunger valves, gate valves, globe valves, ball valves, butterfly valves and combinations thereof. In one embodiment, the valve means comprises at least a pair of ball valves, respectively disposed at the inlet and outlet of the sample capture chamber. In a preferred embodiment, the sample capture

chamber may be fully and intermittently enclosed by at least two three-way ball valves disposed at its inlet and outlet respectively.

The sampling system may further comprise a gas/liquid source in fluid communication with the sample capture chamber and the analyzer means. A carrier gas or a carrier liquid can be introduced from the source to carry the captured sample out of the chamber and to the analyzer means.

10 In one embodiment, a carrier gas is introduced into the sample capture chamber from the gas source, wherein the carrier gas is used to force the captured sample out of the chamber via the outlet and into the analyzer means. In another embodiment, the carrier gas may be used to flush
15 out fluids other than the sample from the sample capture chamber, e.g., a cleaning solvent. The carrier gas may be an inert gas, such as nitrogen or argon. In one embodiment, the carrier gas is nitrogen.

The disclosed sampling system may further comprise a
20 carrier fluid source in fluid communication with the inlet and outlet of the sample capture chamber. The carrier fluid (which can be a gas or a liquid solvent) may be introduced into the chamber after each sampling cycle to dissolve and remove remnant sample that has not been
25 expelled from the chamber. This cleaning procedure can be repeated as necessary until an acceptable level of "cleanliness" is achieved. The level of "cleanliness" can be determined by a self-verification step as further explained below.

30 In another embodiment, the carrier fluid may also be used to provide reference concentrations of particular compounds of interest, e.g., contaminants or a specified

analyte compound. For instance, a small volume of carrier fluid may be captured in the sample capture chamber and thereafter passed towards the analyzer means for analysis, in order to obtain reference concentrations of these compounds of interest. Advantageously, obtaining the reference concentrations of these particular compounds of interest serves as a control and allows a more accurate analysis of the sample to be provided. For example, the analysis results of the sample may be suitably modified to account for the reference concentrations of the compounds by deducting the reference concentration from the analysis results.

Another important aspect of the present application is the ability of the disclosed system to perform self-verification. In particular, by acquiring the reference concentrations of these compounds of interest, an operator can verify the level of cleanliness in the sample capture chamber after a cleaning cycle. For example, if the analyte concentration in the analyzed carrier fluid sample remains significantly higher than a previously determined reference concentration, it would indicate to the operator that there are still sample residues remaining in the sample capture chamber from an earlier sampling cycle, and that additional cleaning is required before a fresh sample can be acquired.

In one embodiment, the carrier fluid may be a liquid solvent. The solvent may be selected from polar or non-polar solvents. In one embodiment, the solvent is n-hexane.

The fluid flow path may be configured to induce a turbulent flow conditions along one or more sections disposed along the fluid flow path, including the sample capture chamber. Advantageously, turbulent flow conditions

facilitate mixing and may allow a homogenous sample to be acquired. In one embodiment, the turbulent fluid flow is characterized by a Reynolds Number of 4000 or more.

The fluid flow path of the disclosed system may
5 comprise a network of interconnectable, branched piping, having a plurality of junctions disposed along said flow path for splitting the fluid flow path into two or more tributary paths, and wherein each junction may comprise one or more valves, for permitting or stopping fluid flow into
10 the tributary paths. In one embodiment, the sample capture chamber is defined by a region of piping that has been isolated by at least two valves.

The piping may be made of stainless steel. The stainless steel piping may also comprise a protective
15 coating on its interior and/or exterior surface. The protective coating can be any suitable coating that is commonly used to confer corrosion resistance, heat and pressure resistance and wear resistance. In another embodiment, the piping may be in the form of tubings.
20 These tubings may be flexible hairline tubings having an internal diameter of less than 0.20 cm.

The piping size may be about 0.3 cm to about 0.6 cm. In one embodiment, the piping is about 0.3175 cm. The internal diameter of the piping may be about 0.15 cm to
25 about 0.20 cm. In one embodiment, the internal diameter is about 0.17525 cm.

The piping may comprise a plurality of bends that are disposed along said fluid flow path and which may be capable of inducing turbulent fluid flow of the sample
30 fluid. The internal surface of the piping may also comprise a plurality of groove formations that induce or promote turbulent fluid flow of said fluid. The housing of

the disclosed system may be a pressure vessel capable of operating at pressures above atmospheric pressure. The pressure vessel housing may be capable of operating at pressures pressure of at least 17,000 kPa.

5 The housing of the disclosed system may also comprise an insulation means to insulate the piping. The insulating means may comprise a heat insulating material that substantially envelopes the external surface of the piping. The insulating means may also comprise a layer of heat
10 insulating material that surrounds the housing. Advantageously, the insulating means minimizes heat transfer between the fluid sample and the external environment, thereby emulating the conditions of the sampling environment. In this way, an accurate
15 representative sample of the chemical and physical state of the sampled stream may be acquired.

In one embodiment, the disclosed housing may comprise a molded modular block having the piping network extending throughout the modular block. In another embodiment, the
20 disclosed housing may be in a form of a panel housing the sampling system therein. It is envisioned that the size of the modular block / panel will be substantially small, allowing it to be transported with ease. The small size and modular nature of the sampling system also confers the
25 ease of retrofitting into existing sampling systems. In one embodiment, the panel / modular block is less than 400 mm by 400 mm in size.

Advantageously, the piping network confers flexibility on the shape of the liquid flow path. Furthermore, the
30 piping network of the sampling system allows it to adopt a compact and modular form. Additionally, it is envisaged

that one or more such modular blocks / panels can be combined in operation to allow a greater rate of sampling.

Due to the structural strength and integrity provided by the piping network, the disclosed sampling system is
5 suitable for receiving a fluid sample from a highly pressurized sampling environment, with pressures ranging from about 6000 kPa (60 bar) to about 12000 kPa (120 bar). In one embodiment, the fluid flow path may have a pressure of at least 17000 kPa (170 bar). Similarly, the disclosed
10 sampling system is also suited to be used in a high temperature sampling environment. The temperature of the sampling environment may range from about 80 °C to about 140° C. In one embodiment, the temperature is at least 120°C.

Advantageously, as the valves can be operated to isolate the capture chamber and trap a fluid sample therein, while the sampling system continues to draw sample fluid from the sampling environment, the disclosed system is capable of being operated in a continuous mode.
20 Advantageously, this allows fluid samples to be drawn and analyzed in a real time mode, making it possible to accurately chart the change in a concentration of one or more analytes over a period of time.

In one embodiment, the sampling environment comprises
25 a bulk stream of hydrocarbons, such as, raw natural gas condensate. As an example, an analyte of interest present in the raw condensate stream may be a toxic substance, such as, mercury.

The disclosed system may comprise analyzing means,
30 which is in fluid communication with the liquid flow path and being configured to analyze the composition of the

representative fluid sample that has been captured by the sample capture means.

The system may also comprise sensing means, which are provided along the liquid flow path for detecting one or
5 more physical parameters of said multiphase multicomponent fluid. These physical parameters may be selected from the group consisting of: temperature, pressure, flow rate, and combinations thereof. In a preferred embodiment, the sensing means may comprise pressure sensors located along
10 the fluid flow path.

The sensing means may also be electronically coupled to the control means and configured to transmit an electronic signal to the control means for activating the valve means when the pressure of the multiphase
15 multicomponent fluid is above the bubble point pressure. In one embodiment, the control means is a programmable logic controller.

The disclosed system may further comprise data collection means configured to record data generated by the
20 analyzer means. In one embodiment, the data collections means may be a computer that is coupled to the analyzer means.

25 **Brief Description of Drawings**

The accompanying drawings illustrate a disclosed embodiment and serves to explain the principles of the disclosed embodiment. It is to be understood, however, that
30 the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention.

Fig. 1A shows a schematic diagram of a manifold sampling system in a default position.

Fig. 1B shows a schematic diagram of a manifold sampling system in a "continuous flow mode" in which sample fluid is flowing continuously through the manifold sampling system.

Fig. 2 shows a schematic diagram of the manifold sampling system in a "sample capturing mode" in which a sample fluid is being captured by the manifold sampling system.

Fig. 3 shows a schematic diagram of the captured sample being released from the manifold sampling system.

Fig. 4a shows a schematic diagram of the sampling system in a "cleaning sequence" wherein a solvent is passed through the manifold sampling system

Fig. 4b shows a schematic diagram of the sampling system, wherein a carrier gas is used to purge the solvent present in the manifolds.

Fig. 5a shows a schematic diagram of the sampling system in a "verification sequence", wherein a solvent (instead of fluid sample) is passed continuously through the manifold sampling system.

Fig. 5b shows a schematic diagram of the sampling system in a "verification sequence", wherein a volume of solvent is being captured by the manifold sampling system.

Fig. 5c shows a schematic diagram of the sampling system in a "verification sequence", wherein the captured volume of solvent is being released from the manifold sampling system for analysis.

Fig. 6 shows a schematic diagram of another exemplary embodiment of the described sampling system in a default position, wherein all the valves are in a default "stop"

position and there is no flow of liquid sample within the device.

Fig. 7 shows the sampling system of Fig.6 in a sampling mode where a fluid sample is drawn from a sampling
5 environment.

Fig. 8 shows the sampling system of Fig. 6 in a "sample trapping" mode where a body of sample fluid is trapped.

Fig. 9 shows the sampling system of Fig. 6, where the
10 trapped sample fluid is discharged.

Fig. 10a shows the sampling system of Fig. 6 in a first part of a cleaning sequence.

Fig. 10b also shows the sampling system of Fig. 6 in a second part of a cleaning sequence

Fig. 11a shows the sampling system of Fig. 6 in a
15 verification sequence, where solvent is flushed through the sampling system.

Fig. 11b shows the sampling system of Fig. 6 in a
20 verification sequence, where a small volume of the solvent is captured.

Fig. 11c shows the sampling system of Fig. 6 in a verification sequence, where the captured solvent is discharged for further analysis.

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Detailed Description of Drawings

Now referring to Fig. 1A, there is shown one particular embodiment of a manifold sampling system 100
30 according to the present disclosure in a default position.

The sampling system 100 comprises a network of stainless steel manifold pipes 30 which forms an internal

conduit for a fluid to flow therethrough. A plurality of three-way ball valves(4, 8, 10, 16, 22) are provided at various junctions of the network of manifold pipes 30. A sample trapping zone 18 is provided along the internal
5 conduit, which is enclosed by valves 8 and 16. In a default position, all the valves remain in a closed position and no fluid enters or leaves the system 100. This default position is capable of serving as a safety-interlock sequence.

10 Fig. 1B shows the sampling system 100 in a sampling sequence, where a sample fluid stream enters the system 100 via a sample inlet 2. The fluid flow path of the sample fluid is indicated by a series of arrows occurring within the manifold pipes 30. A first three-way ball valve 4 is
15 provided adjacent the sample inlet 2 for regulating inflow of sample fluid into the system 100. When sample fluid is not desired for admission into the system, valve 4 can be configured to direct fluid flow towards a sample outlet 32.

When in a sampling sequence, however, valve 4 directs
20 the sample fluid towards a second three way ball valve 6, which in turn directs the sample fluid into sample capture zone 18. Sample capture zone 18 is formed by a section of the internal conduit which is enclosed by two three way ball valves 8 and 16. During the sampling sequence, both
25 valves 8 and 16 are configured to allow continual passage of the sample fluid past the sample capture zone 18 and towards another three-way ball valve 22, which discharges the sample fluid out of the system 100 via a second sample outlet 24.

30 The sampling sequence is maintained for approximately one minute prior to activating the next sequence, i.e, sample capturing sequence. However, this time may be

dependent on the actual flow rate of the sample fluid through the system 100. It is merely desired that a steady state be achieved prior to capturing a sample.

Now referring to Fig. 2, there is shown the sampling system 100 of Fig. 1A in a sample capturing sequence. For clarity and consistency, the same numerals will be used to refer to the same components of system 100 throughout Figs. 1 to 5c.

During the sample capturing sequence, valve 16 is switched to prevent passage of fluid sample out of the sample capturing zone 18. Within two seconds or less, valve 8 is similarly closed to completely trap a volume of sample fluid within the sample capturing zone 18. At the same time, valve 4 is configured to stop inflow of the fluid sample. Incoming fluid sample is continually being discharged through sample outlet 32. The sample capturing sequence is typically completed within a time frame of five seconds or less. Due to the synchronous sealing of the valves, the captured sample fluid experiences minimal pressure loss and is at substantially the same pressure as the sample fluid flowing within the internal conduit of system 100. It is preferred that this pressure is above the bubble point pressure of the sample fluid to maintain the captured sample in a substantially single phase state.

Now referring to Fig. 3, valve 8 is opened to allow the captured fluid sample to flow towards a three-way ball valve 10. Almost simultaneously, a carrier gas is introduced into the system 100 via a carrier gas inlet 28. Valve 16 is suitably adjusted to direct carrier gas flow into the sample capture zone 18, which forces the captured fluid out of the sample capture zone 18 and towards valve 10. At this point, valve 10 is configured to discharge the

captured fluid out of the system 100 via an outlet 12 and into a sample conversion unit (not shown). Once converted into an analyzable form, the converted sample may then be sent into an analyzing unit for further analysis. The
5 introduction of carrier gas and discharge of captured sample fluid is undertaken within a time frame of 15 seconds or less.

After the discharge of the captured sample, the system 100 is now ready to activate a cleaning sequence, as
10 exemplified by Figs. 4a and 4b. Referring to Fig. 4a, a solvent (which can be polar or non-polar depending on the sample fluid composition) is introduced into the system 100 via a solvent inlet 26. A three way ball valve 22 is disposed adjacent to inlet 26 and serves to regulate the
15 inflow of solvent. During the cleaning sequence, valve 22 is configured to direct solvent flow towards valve 16. Valve 16 is thereafter adjusted to allow the solvent to pass into the sample capture zone 18. This is followed by an adjustment in valve 8 which thereafter directs the
20 solvent towards valve 10. At this point, valve 10 is configured to discharge the solvent out of the system 100 via a solvent waste outlet 14. In this manner, a continuous flow of solvent within the internal conduit is established and maintained for approximately 2.5 minutes or
25 lesser.

After a desired length of cleaning time has been reached, the system 100 then proceeds into a second step of the cleaning sequence as exemplified by Fig. 4b. Valve 22 becomes closed and no longer admits fresh solvent into the
30 system 100. Thereafter, valve 16 is adjusted to allow passage of the carrier gas into the sample capture zone 18, where the resident solvent is forced out of the sample

capture zone 18 by the pressure of the carrier gas. At this time, valve 8 is open such that the carrier gas, along with the solvent, is passed towards valve 10 and thereafter discharged out of the system 100 via solvent waste outlet 14. The purging of solvent from the system 100 using a carrier gas is undertaken for a time frame of 10 seconds or lesser.

Another important aspect of the disclosed sampling system lies in its ability to perform self-verification, i.e., the disclosed system is able to verify the cleanliness of the internal conduit, in particular the sample capture zone 18, after the cleaning sequence of Figs. 4a-4b. This self-verifications sequence is exemplified by Figs. 5a-5c.

Now referring to Fig. 5a, a solvent is introduced into the system 100 via the solvent inlet 26. Valve 22 directs the solvent flow towards the sample capture zone 18. At the same time, valve 16 and 8 are configured to allow passage of the solvent through the sample capture zone 18. During the self verification sequence, valve 8 directs the solvent towards valve 6 rather than valve 10. Valve 6 is configured to thereafter discharge the solvent through a separate solvent waste outlet 34. In this manner, a continuous flow of solvent is established. This step is undertaken for about 5 seconds or less.

Now referring to Fig. 5b, a volume of solvent is captured within the solvent capture zone 18. During this capturing sequence, valve 8 is closed and quickly followed by valve 16 after two seconds or lesser, thereby capturing a volume of solvent within the sample capture chamber zone 18. Valve 22 is closed and stops further inflow of solvent into the system 100 whereas valve 6 is configured to

prevent further discharge of solvent out of solvent waste outlet 34. This solvent capturing step is undertaken for about 5 seconds or lesser.

Fig. 5c shows the discharge of the captured solvent via the introduction of a carrier gas. Firstly, valve 8 is opened and permits the captured solvent to flow towards valve 10. This is quickly followed by the opening of valve 16 to allow passage of carrier gas towards the sample capture zone 18. The pressure of the carrier gas then forces the captured solvent out of the capture zone 18 and towards valve 10. Valve 10 is configured to discharge the captured solvent into a conversion unit (not shown) via outlet 12, wherein the captured solvent is converted into an analyzable form for further analysis. This analysis may provide reference concentrations of the one or more analytes of interest. These reference concentrations may then be compared with reference concentrations recorded from an earlier verification sequence to determine if an acceptable level of cleanliness has been reached. Once an operator is satisfied that the system 100 is sufficiently cleaned, the system 100 is then ready to admit a fresh fluid sample in accordance with Fig. 1B.

Referring now to Fig. 6, there is shown a sampling system 200 in accordance with another embodiment of the present disclosure, wherein the sampling system 200 is shown in a default position, i.e., all the valves are configured to stop any flow of fluid sample within the system. The sampling system 200 can be housed within a small panel (not shown), approximately 400 mm by 400 mm in size, and comprises a plurality of interconnected piping 216, which defines a fluid flow path for a multiphase fluid sample to flow therethrough. The piping is made of coated

stainless steel, which is capable of withstanding high temperatures (up to 120 °C) and high pressures (up to 170 bar absolute). The piping 216 is about 1/8 inches in size and comprises an internal diameter of about 0.059 inches or
5 less.

A multiphase, multicomponent, highly pressurized hydrocarbon (HC) fluid sample is drawn from a sampling environment (not shown) and enters the sampling system 200 via sample inlet 202. The HC fluid sample is passed
10 through a filter 218, whose pore size is configured to remove large particulate material. A sufficiently large pore size also ensures that any pressure drop across the filter is minimized. As the piping 216 is robust enough to tolerate small particulate matter without running the risk
15 of clogging, additional filters with smaller pore sizes are advantageously not required.

A plurality of three-way ball valves 204, 206, 208, 210 and 212 are provided along piping 216 to permit or prevent flow of the fluid sample. The valves are powered
20 by pneumatic motors (for valves 204, 210, 212) or stepper motors (for valves 206, 208) respectively. The mechanical operations of these actuators are well-known in the art and will not be further discussed herein. However, any suitable actuator may be used in conjunction with the three way
25 valves and the figures should not be construed as limiting the valves to the disclosed actuators. The shaded portions of the valves denote a "stop" configuration where no passage of the HC fluid sample is permitted, whereas a clear portion denotes a "flow" configuration where the
30 fluid sample is allowed to pass through. In the default position, all the valves adopt a 90° stop position as shown in Fig. 6.

Valve 204 is disposed closest to the sample inlet 202 and regulates the influx of sample into the sampling system 200. In one configuration, valve 204 may transmit incoming fluid sample towards a waste outlet 220. In another
5 configuration, valve 204 may transmit incoming fluid sample towards valve 206. In another configuration, valves 206 and 208 may act in tandem to define an enclosed sample capture chamber 214 about 1 cm³ in volume in order to capture a fluid sample therein.

10 Valve 206 can be configured to transmit the captured fluid sample towards valve 210 once a desired residence time is achieved in the sample capture chamber 214. Valve 210 can be configured to either transmit the fluid sample received from valve 206 into a pre-conversion unit 222 or
15 when the trapped sample is not required to be analyzed, valve 210 may simply be configured to discharge the captured fluid sample out of the system via a waste outlet 224. Valve 212 can be configured to discharge free, excess sample fluid remaining in the piping via a sample outlet
20 226. An inlet 228, in fluid communication with valve 212, is provided to admit a cleaning solvent into the sampling system. The solvent may be used to flush the interior surface of piping 216 to dissolve and remove remnant sample residues. Another inlet 230, in fluid communication with
25 valve 208, is provided to admit a carrier gas. The carrier gas may be used to purge the piping of any remnant sample or solvent which were not discharged after a previous sampling cycle.

For consistency and clarity, the same numbering system
30 as used in Fig. 6 will be used henceforth to refer to the same components in Figures 7 to 11a-11c.

Fig.7 shows the same sampling system 200 as Fig. 6, now in a sampling mode. A multiphase, highly pressurized, HC fluid sample enters the sampling system by means of sample inlet 202. The HC fluid sample passes through filter 218 for removal of large particulate material and flows towards valve 204. Valve 204 is selected to be in a 0° stop position, to direct sample fluid flow towards valve 206 whilst stopping flow towards waste outlet 220. Valves 206 and 208 are configured in a 0° stop and 180° stop position respectively, such that the fluid sample flows continuously in and out of sample capture chamber 214, whilst valve 212 is configured to permit fluid flow out of sample outlet 226. In this manner, a continuous flow of HC sample in and out of system 200 is established. This continuous flow is maintained for one minute before the next sequence (i.e. sample trapping).

Now referring to Fig. 8, there is shown the sampling system 200 in a sample trapping sequence. A series of ultra rapid changes in valve positions results in a body of HC fluid sample being isolated within sample capture chamber 214. In particular, valve 208 first switches position to a 90° stop position, wherein sample fluid flow towards valve 212 is cut off. Two seconds or less later, valve 206 also rapidly switches to a 90° stop position, wherein valve 206 stops receiving inflow of fluid sample from valve 204. Approximately a second later, valves 204 and 212 are closed in a 90° stop position, whereby valve 204 stops admitting fluid sample from inlet 202 and valve 212 prevents further discharge of fluid sample through outlet 226. The position of valve 210 is unchanged from the previous sequence.

Through this rapid sequence of valve switching, an isolated volume of fluid sample is captured within the sample capture chamber 214. As the complete sequence of valve switching is undertaken rapidly, the pressure of the sample capture chamber 214 is maintained substantially the same as the pressure in the fluid flow path, preferably above the bubble point pressure of the fluid sample, such that the captured sample is isolated as a single phase, liquid sample. Furthermore, due to the flow conditions within the sample capture chamber 214, the single phase liquid sample becomes homogeneously mixed. The entire valve switching sequence is undertaken for a time period of less than 5 seconds in total. Once all the valve positions are switched appropriately and the single phase liquid sample has been sufficiently homogenized, the sampling system 200 then progresses to a sample release sequence.

Referring to Fig. 9, there is shown the sampling system 200 in a sample release mode. Valve 206 switches to a 180° stop position, quickly followed by valves 208 and 210 which adopt a 0° stop position and a 180° stop position respectively. The captured liquid sample in chamber 214 is permitted to flow towards valve 210 and is thereafter discharged into a pre-conversion unit 222 where the liquid sample is further processed prior to undergoing analysis. The positions of valves 204 and 212 remain unchanged and continue to stop inflow and outflow of sample to and from sampling system 200. A carrier gas is introduced from gas inlet 230, which is fluidly communicated with valve 208 and chamber 214. The pressurized flow of carrier gas helps to purge the captured liquid sample out of the chamber 214 and into the pre-conversion unit 222.

Figures 10a and 10b show a cleaning sequence whereby, after discharging the captured liquid sample, a solvent is introduced into the sampling system to clean the interior of piping 216.

5 Referring now to Fig. 10a, valve 208 adopts a 180° position and is quickly followed by the simultaneous switching of valves 210 and 212, which adopt a 0° and 180° stop position respectively. Valves 204 and 206 experience no switching in positions. A solvent is introduced into
10 the sampling system 200 via solvent inlet 218. The solvent passes through valve 212, valve 208, chamber 214, valve 206, valve 210 and is discharged out of waste outlet 224. When passing through the sample capture chamber 214, the solvent dissolves remnant sample adhering to the interior surface
15 of chamber 214 and carries the remnant sample out of the system 200.

After cleaning with the solvent, the chamber 214 is further purged with a carrier gas as shown in Fig. 10b. During gas purging, valve 212 is switched to a 90° stop
20 position to stop solvent influx. Valve 208 is then quickly switched to a 0° stop position to permit passage of carrier gas entering from inlet 230 into the chamber 214. The carrier gas then purges the solvent out of the system 200 via waste outlet 224.

25 Another important aspect of the presently described sampling system 200 lies in its ability to perform loop verification. This process involves flushing the piping, including the chamber 214, with the solvent, isolating a defined volume of solvent in the chamber 214 and
30 subsequently purging the isolated solvent out of the system 200 with a carrier gas and into a pre-conversion unit 222. The discharged solvent is then analyzed in order to provide

reference concentrations of one or more compounds of interest. These reference concentrations can be subsequently accounted for and appropriately deducted from subsequent analysis of the HC samples in order to provide a more accurate concentration of the compound of interest. The loop verification sequence is exemplified by Figures 11a, 11b and 11c.

Referring now to Fig. 11a, valve 204 is selected to be in a 180° stop position, restricting inflow of HC sample. Approximately two seconds later, valve 206 is switched to a 0° stop position, whereas concurrently, valves 208 and 212 each adopt a 180° stop position. Solvent is introduced at inlet 218 and flows continuously through valve 212, valve 208, trapping region 214, valve 206, valve 204 and out of the device through outlet 220. This continuous flow of solvent is maintained for at least two seconds.

Fig. 11b shows the isolation of the solvent within chamber 214. In particular, valve 206 switches to a 90° stop position and this is followed by valve 208 after approximately two seconds. A second later, valves 204 and 212 concurrently switch to a 90° stop position, thereby isolating a small volume (1 cm³) of solvent within chamber 214. The trapped solvent is thereafter homogenously mixed in chamber 214 and is ready for discharge. Fig. 11c shows the discharge of the isolated solvent via the introduction of a carrier gas. Specifically, valve 206 switches to a 180° stop position to allow passage of solvent towards valve 210. Valves 208 and 210 then concurrently switch to a 0° stop position and a 180° stop position respectively. Valve 208 allows the carrier gas entering from inlet 230 to purge the trapped solvent from chamber 214 towards valve 206, valve 210 and finally discharges the solvent out of

the system 200 and into the pre-con unit 222. The discharged solvent may be further processed and subsequently analyzed in order to provide reference concentrations of the one or more analytes of interest.

5 Once the reference concentrations have been obtained, the sampling system 200 is ready to receive the multiphase HC fluid sample in accordance with Fig. 6.

The progression from one sequence to another as exemplified through Figs. 7 to 11a-c may be controlled by a
10 programmable logic controller (PLC). The PLC is programmed with a pre-determined logic to activate an appropriate set of valves once a pre-defined set of conditions have been met, in order to enable the sampling system to switch from one sequence to another. For example, pressure sensors are
15 installed at various locations along the fluid flow path, e.g., downstream of inlet 202, which are electronically coupled with the PLC. Once a pre-determined pressure value (which can be set or adjusted by the operator) is detected by the sensors and communicated to the PLC, a series of
20 valve switching may be triggered to progress from one sequence to another.

Applications

25 The described sampling system is capable of drawing samples from a high pressure and temperature sampling environment. The described system is also useful for obtaining and analyzing a high pressure multiphase, multicomponent fluid from a sampling environment, for
30 instance, hydrocarbon crackers, distillation columns, blenders, etc.

In particular, the piping network used in the disclosed sampling system is of a sufficiently wide internal diameter and therefore prevents any clogging by particulate material which are typically present in hydrocarbon samples. The disclosed piping network is also robust and resistant to high pressure and temperature conditions, thereby allowing the sampling system to acquire samples from a high pressure and temperature sampling environment, while at the same time minimizing the risks caused by structural leakage and preventing harm from being caused to personnel withdrawing the samples.

The disclosed system also comprises a sample capture chamber, where the fluid sample is isolated for a short period of time under turbulent conditions, thereby allowing good mixing of the liquid sample. The disclosed system is also capable of trapping a multiphase fluid sample as a single phase liquid sample, thereby ensuring that substantially all the analyte is captured within the liquid sample. Advantageously, the described sampling system is capable of providing a representative sample of the sampling environment for accurate analysis.

Furthermore, through the advantageous arrangement of the piping network and the automated or semi-automated valve means, the described sampling system is further capable of continually drawing sample from the sampling environment, whilst at the same time, intermittently isolating and discharging a small volume of liquid sample for analysis. Advantageously, this allows the sampling system to be operated in a continuous mode. Further advantageously, this allows the described sampling system to detect and measure real time changes in the analyte composition in the sampling environment.

It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of
5 the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Claims

1. A sampling system for obtaining a representative fluid sample from a high pressure multiphase multicomponent fluid, the system comprising:

5 a fluid flow path for transmitting the high pressure multiphase multicomponent fluid therethrough, the pressure of the fluid flow path being substantially the same as the pressure of an environment to be sampled;

10 a sample capture chamber in direct fluid communication with the fluid flow path and having an inlet for receiving the high pressure multiphase multicomponent fluid therein and an outlet for expelling the high pressure multiphase multicomponent fluid therefrom;

15 valves means configured to fluidly seal the inlet and outlet of said sample capture chamber and thereby capture the representative fluid sample of the high pressure multiphase multicomponent fluid as it passes therethrough; and

20 control means for controlling the valve means so that the pressure of said representative fluid sample is substantially the same as the high pressure multiphase multicomponent fluid in said fluid flow path.

25 2. The system as claimed in claim 1, wherein said pressure in said fluid flow path is above the bubble point pressure of the multiphase multicomponent fluid.

30 3. The system as claimed in claims 1 or 2, wherein said sample capture chamber has a pre-determined fixed volume when said valve means have sealed said inlet and outlet.

4. The system as claimed in any one of claims 1 to 3,
wherein said valve means unseals said outlet of said sample
capture chamber to release said captured sample contained
5 therein.

5. The system as claimed in claim 4, wherein said
outlet is in fluid communication with analyzer means
configured to analyze the components of the released sample.
10

6. The system as claimed in claim 4 or claim 5,
wherein the released sample experiences a drop in pressure,
resulting in flashing of one or more compounds present
within the sample, causing the formation of a multiphase
15 fluid.

7. The system as claimed in any one of the preceding
claims, wherein said control means is configured to actuate
the valve means such that the inlet and outlet of the
20 sample capture chamber are synchronously fluidly sealed.

8. The system as claimed in any one of the preceding
claims, wherein said synchronous fluid sealing of said
inlet and outlet of said sample capture chamber is
25 undertaken to substantially maintain the fluid pressure
within the sample capture chamber as the fluid pressure of
the fluid flow path.

9. The system as claimed in any one of the preceding
30 claims wherein said control means comprises a network of
sensors that monitor the pressure of the fluid flow path.

10. The system as claimed in claim 9, wherein said control means further comprises a network of actuators that are operably linked with the sensors and valve means to fluidly seal said sample capture chamber.

5

11. The system as claimed in any one of the preceding claims, wherein the valve means comprises valves selected from the group consisting of ball valves, isolation valves and shut-off valves.

10

12. The system as claimed in any one of the preceding claims, wherein said system further comprises a carrier fluid source for removing said sample from said sample capture chamber.

15

13. The system as claimed in claim 12, wherein said carrier fluid source is in fluid communication with the inlet and outlet of said sample capture chamber.

20

14. The system as claimed in any one of claims 5 to 13, wherein said system further comprises a gas source in fluid communication with said sample capture chamber and said analyzer means.

25

15. The system as claimed in claims 12 and 13, wherein said carrier fluid source and said gas source are in fluid communication with the fluid flow path.

30

16. A method for obtaining a representative fluid sample from a high pressure multiphase multicomponent fluid, the method comprising the steps of:

(a) providing a fluid flow path for transmitting the high pressure multiphase multicomponent fluid therethrough;

(b) providing a sample capture chamber in direct fluid communication with the fluid flow path and having an inlet
5 for receiving the high pressure multiphase multicomponent fluid therein and an outlet for expelling the high pressure multiphase multicomponent fluid therefrom;

(c) fluidly sealing the inlet and outlet of said sample capture chamber with a valve means and capturing the
10 representative fluid sample from the high pressure multiphase multicomponent fluid as it passes through the sample capture chamber; and

(d) controlling the valve means so that the pressure of said representative fluid sample is substantially the
15 same as the high pressure multiphase multicomponent fluid in said fluid flow path.

17. The method according to claim 16, wherein said pressure in said fluid flow path is above the bubble point
20 pressure of said multiphase multicomponent fluid.

18. The method according to any one of claims 16 or 17, further comprising the step of unsealing the outlet of the sample capture chamber to release the captured sample
25 contained therein.

19. The method according to any one of claims 16 to 18, said method further comprising the step of passing the released sample into an analyzer means configured to
30 analyze the components of the released sample.

20. The method according to any one of claims 16 to 19, wherein step (c) comprises synchronously sealing the inlet and outlet of the sample capture chamber.

- 5 21. The method according to claim 20, wherein said synchronous sealing is undertaken to substantially maintain the fluid pressure within the sample capture chamber as the fluid pressure of the fluid flow path.