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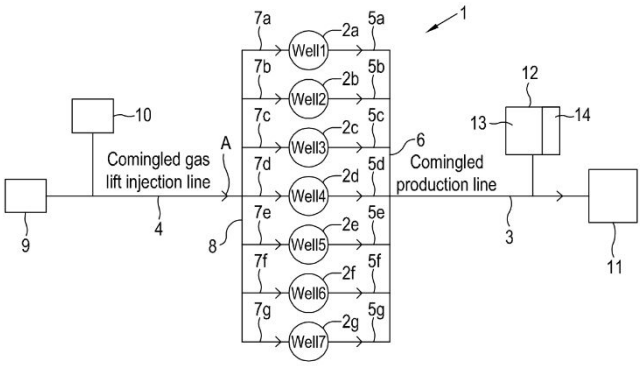
(54) Title **DETERMINING GAS LIFT PERFORMANCE PROPERTIES**

(57) Abstract

Gas lift performance properties for one or more wells of a group of gas lift wells coupled to a common production line can be determined using various methods and apparatus. Examples include fluid being produced from a first plurality of the gas lift wells, a first fluid composition response being obtained associated with first gas lifted production fluid in the common production line, fluid being produced from a second plurality of the gas lift wells, the second plurality of the gas lift wells including at least two, and excluding at least one, of the first plurality of gas lift wells, a second fluid composition response being obtained associated with second gas lifted production fluid in the common production line, and the first and second responses being used to determine at least one gas lift performance property for the one or more wells.



DETERMINING GAS LIFT PERFORMANCE PROPERTIES

The present invention relates to gas lift wells and, in particular, to the determination of gas lift performance properties.

In the production of oil and gas from wells, gas lift is sometimes applied to a well to help to move produced fluid from the subsurface reservoir toward surface. Such a well is termed herein a gas lift well. As is well known, gas lift typically involves injecting a lift gas into the production tubing in the well at one or more downhole locations along the tubing. The production tubing has openings at suitable locations along the tubing, the openings typically provided through gas lift valves, for entering the lift gas into the tubing. The lift gas acts to reduce the effective weight and hydrostatic pressure of produced fluid in the production tubing. The drive of produced fluid toward surface effected by reservoir pressure may therefore be maintained or enhanced and increase the production rate.

In prior art, an individual gas lift well can be tested as to whether the gas lift is performing properly and/or as intended. One method involves injecting a tracer gas into the lift gas which then enters the production tubing at the desired tubing entry locations. The tracer gas then returns to surface in the flow out of the well together with the produced fluid and the lift gas and is detected at the surface for example using the Shkorin Gas Analyser as marketed by Scanwell AS. Gas lift properties such as the lift gas composition and lift gas rate can be detected. Returns of the tracer gas from the different downhole tubing entry locations along the production tubing can be detected and measured as a function of time, correlating with the depth(s) that the lift gas enters. Methods are also described in PCT patent publication number WO2019/325936 in the name of Scanwell Technology AS.

In the production of oil and gas from a plurality of subsea gas lift wells tied to subsea well template, there is typically provided a comingled gas lift injection pipe for containing the lift gas from surface flowing to the template and to be distributed into the plurality of subsea wells and a comingled gas lift production pipe for containing production fluid combined from the plurality of the subsea wells flowing from the template toward surface.

The inventors note that whilst existing techniques for determining gas lift properties and testing the gas lift performance can be applied on the production and/or injection lines of one individual well, there is a need for solutions adapted for subsea infrastructures from multiple subsea gas lift wells using templates and/or comingled production and/or injection lines, noting that the opportunity for obtaining tracer returns from one well in such contexts may be limited or unfeasible.

According to a first aspect of the invention, there is provided a method of determining at least one gas lift performance property for one or more wells of a group of gas lift wells coupled to a common production line, the method comprising the steps of: (a) producing fluid from a first plurality of gas lift wells of said group, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the production tubing in each of the first plurality of gas lift wells, conveying first gas lifted production fluid from the first plurality of gas lift wells through the common production line; (b) using at least one fluid composition detector, obtaining a first fluid composition response associated with the first gas lifted production fluid in the common production line; (c) producing fluid from a second plurality of gas lift wells of said group, the second plurality of gas lift wells including at least two gas lift wells of the first plurality of gas lift wells and excluding at least one gas lift well of the first plurality of gas lift wells, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the production tubing in each of the second plurality of gas lift wells, conveying second gas lifted production fluid from the second plurality through the common production line; (d) using at least one fluid composition detector, obtaining a second fluid composition response associated with the second gas lifted production fluid in the common production line; and (e) using the first and second responses to determine the gas lift performance property for the one or more wells of the group.

In this way, production from several wells can be maintained, yet through the exclusion of at least one well, a different fluid composition response from the combined production fluid from the second plurality of wells can be obtained such that one or more features in the response from the first plurality of wells can be further analysed and/or related to the excluded well(s).

Typically, the second plurality excludes one gas lift well of the first plurality and includes each of the other gas lift wells of the first plurality.

Optionally, the second plurality excludes two gas lift wells of the first plurality and includes each of the other gas lift wells of the first plurality.

Typically, the method further comprises: producing fluid from a further plurality of gas lift wells, the further plurality excluding another gas lift well of the first plurality and including each of the other gas lift wells of the first plurality, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the production tubing in each of the further plurality of gas lift wells, conveying gas lifted production fluid from the further plurality through the common production line, using at least one fluid composition detector, obtaining a further fluid composition response associated with the production fluid in the common production line, and further using the further response to determine the gas lift performance property.

The production of fluid from the further plurality of gas lift wells and the obtaining of the further response may be performed with a different well excluded and repeated until each of the wells of the first plurality has been excluded.

Typically, step (e) is performed to determine the gas lift performance property for the excluded well.

Step (e) may include identifying one or more differences between the first and second responses and based on the one or more differences determining the gas lift performance property. The method may further comprise comparing the responses to identify one or more differences.

The method may further comprise using the determined gas lift performance property to determine a fault or condition of the one or more gas lift wells and/or one or more components thereof.

The method may include shutting the well to be excluded from the second plurality.

Step (a) may be performed before step (c) or vice versa.

Any of the first, second, and further fluid composition responses may be or may comprise fluid composition data. The fluid composition data may be time series data. The data may comprise data records of detected concentration or detected amounts of one or more detected fluid components of the production fluid such as the tracer gas.

In certain examples, any of the first, second, and further fluid composition responses may be a tracer fluid concentration response. The tracer fluid concentration response may comprise tracer fluid concentration data, which may comprise detected concentration or amounts of the tracer fluid in the production fluid in the common production line. The tracer fluid concentration data may be time series data. The tracer fluid concentration data may comprise detected concentration or amounts of the tracer fluid in the production fluid in the common production line. The tracer fluid may be or comprise tracer gas.

In certain examples, the group of gas lift wells may be further coupled to a common lift gas line, and the method may then include the step of conveying lift gas and inserted tracer fluid through the common lift gas line.

According to a second aspect of the invention, there is provided a method of determining at least one gas lift performance property in a system in which a plurality of gas lift wells are coupled to a common production line, the method comprising the steps of: (p) producing fluid from a first gas lift well, a second gas lift well, and a third gas lift well of said plurality, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the production tubing in each of the first, second, and third gas lift wells, conveying combined gas lifted production fluid from the first, second, and third gas lift wells through the common production line, and using at least one fluid composition detector, obtaining a first fluid composition response associated with the fluid in the common production line; (q) producing fluid from the first gas lift well and the second gas lift well, third gas lift well being shut, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the

production tubing in each of the first and second gas lift wells, conveying combined gas lifted production fluid from the first and second gas lift wells through the common production line, and using at least one fluid composition detector, obtaining a second fluid composition response associated with the fluid in the common production line; (r) using the first and second responses to determine the gas lift performance property for one or more of the first, second, and third gas lift wells.

The method may further comprise the step of: (s) producing fluid from the first gas lift well and the third gas lift well, the second gas lift well being shut, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the production tubing in each of the first and third gas lift wells, conveying combined gas lifted production fluid from the first and third gas lift wells through the common production line, using at least one fluid composition detector, obtaining a third fluid composition response associated with the fluid in the common production line, for the first and third gas lift wells combined; and the step (r) may include further using the third response to determine the gas lift performance property for the one or more of the first, second, and third gas lift wells.

The method may further comprise the step of: (t) producing fluid from the second gas lift well and the third gas lift well, the first gas lift well being shut, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the production tubing in each of the second and third gas lift wells, conveying combined gas lifted production fluid from the second and third gas lift wells through the common production line, using at least one fluid composition detector, obtaining a fourth fluid composition response associated with the fluid in the common production line for the second and third gas lift wells combined; and the step (r) may include further using the fourth fluid composition response to determine the gas lift performance property for the one or more of the first, second, and third gas lift wells.

The method may include injecting or inserting the tracer fluid into at least one lift gas supply line. The method may further include supplying the lift gas and inserted

tracer fluid to the producing gas lift wells. The injection or insertion of the tracer fluid may be performed intermittently.

The tracer fluid may be injected or inserted into the at least one gas lift supply line at known or measured time intervals and/or in known or measured amounts. The tracer fluid in the lift gas supply line may have known or measured concentration or may have a known or measured composition.

The tracer fluid may comprise or be tracer gas. The tracer gas may be nitrogen gas or carbon dioxide gas.

The fluid composition response, e.g. any of the abovementioned first, second, third, fourth, or further fluid composition response, may comprise fluid concentration data, for example, tracer fluid concentration data.

The fluid composition detector may be or comprise a tracer fluid detector.

According to a third aspect of the invention, there is provided apparatus for determining at least one gas lift performance property for one or more wells of a group of gas lift wells coupled to a common production line, the apparatus comprising: at least one fluid composition detector for obtaining fluid composition data associated with fluid received in the common production line from the gas lift wells; and determiner means configured to receive fluid composition data from the detector, the determiner being further configured to determine the gas lift performance property based upon first fluid composition data from the production of gas lift production fluid from the first plurality of gas lift wells and second fluid composition data from the production of gas lift production fluid from the second plurality of wells.

Any of the abovementioned aspects of the invention may have one or more further features as described in relation to any other of the various aspects of the invention wherever described herein.

Embodiments of the invention may be advantageous in various ways as will be apparent from throughout herein.

There will now be described, by way of example only, embodiments of the invention with reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of a system in accordance with an embodiment of the invention;

Figure 2 is schematic representation of wells of the system of Figure 1;

Figure 3 is a representation of time series first and second fluid composition responses obtainable through use of the system of Figure 1;

Figure 4 is a representation of various gas lift performance properties obtainable from the system.

Turning to Figure 1, a system 1 is generally depicted including a plurality of gas lift wells, in this example seven subsea gas lift wells 2a-2g. The wells 2a-2g are coupled to common production line 3 and a common lift gas line 4. The wells 2a-2g connect through respective connecting lines 5a-5g through subsea combiner 6 to the production line 3. The wells 2a-2g connect through respective connecting lines 7a-7g through subsea distributor 8 to the lift gas line 4.

The system 1 includes lift gas supply means 9 for supplying lift gas through the lift gas line 4. The common lift gas line 4 conveys lift gas for onward distribution, subsea, into the wells 2a-2g via the distributor 8 and connecting lines 7a-7g.

The system 1 further includes tracer insertion means 10 for inserting tracer into the common lift gas line 4. In the lift gas line 4, the tracer together with the lift gas is conveyed onward toward the wells 2a-2g, as indicated by arrow A.

As can be appreciated with additional reference now to Figure 2, which depicts for exemplification purposes only the wells 2a-2c, the lift gas is further conveyed downhole into each well. Each well has a wellbore 31 extending below seabed 32 and production tubing 34 therein. Production fluid comprising fluid from the reservoir is communicated upward from toward surface inside the production tubing 34 as indicated by arrows B. The lift gas with inserted tracer enters through openings 34e into the production tubing 34 in the wellbore of the well at various locations along the production tubing 34. Production flow or rate from each well

may through the lift gas thus be enhanced. The gas lift production fluid including lift gas, tracer, and reservoir fluid is extracted from each well.

The production fluid is conveyed onward through the connecting lines 5a-5g and the combiner 6 into the common production line 3. The common production line 3 is thus arranged to contain and convey the commingled or combined production fluid from the wells 2a-2g coupled to it.

The system 1 includes a downstream facility 11, for example comprising a test separator, coupled to the common production line 3. The production fluid from the wells is conveyed through the common production line 3 onward toward the downstream facility 11, e.g. test separator.

The system 1 further includes an apparatus 12 for determining gas lift performance properties for one or more of the wells 2a-2b. The apparatus 12 includes a gas composition detector 13 for acquiring gas composition data for the production fluid in the common production line. The acquired composition data comprises for example tracer gas concentrations. The gas composition detector 13 is for example a gas composition analyser for detecting and determining the composition of gas in the production fluid in the common production line. The gas composition is detected in response to insertion of tracer gas into the system and return of the tracer gas with the production fluid from the producing gas lift wells in the production fluid, and as can be appreciated, this return of tracer gas depends upon the position and configuration of the well and lift gas entry locations along the production tubing. The apparatus 12 further includes determiner means 14 which is configured to determine the gas lift performance property from detections made by the detector 13, as will now be further described.

With reference further to Figure 3, the time series gas composition response curve 41 of tracer gas concentration in the common production line versus time is shown when all gas lift wells 2a-2g are producing. By comparison, the time series response curve 42 of tracer gas concentration in the common production line is shown when one of the wells is shut, e.g., the well 2c is shut, and all others of the gas lift wells are producing. As can be seen at time t, the curve 41 contains a return feature 41f which is not present and missing in the curve 42. From this it

can be ascertained that the return feature 41f seen in the curve 42 is associated with the well 2c which is shut. Other attributable differences could be differences in the magnitude of peaks or troughs between curves. Thus, the difference in the gas composition responses from one plurality with each well producing and another plurality excluding one well and including the others, can therefore allow determination of the gas lift property of the excluded well. This process can be repeated for each of the wells, one being shut at a time. Advantageously therefore, individual wells can in this way be analysed for their tracer gas and gas lift performance properties.

The determiner means 14 is configured to determine gas lift performance property of one or more of the wells based upon first gas composition data associated with the production of gas lift production fluid from a first plurality of gas lift wells and second gas composition data associated with the production of gas lift production fluid from a second plurality of wells, wherein the second plurality excludes one well and includes the other wells of the first plurality.

In some examples, a method of determining a gas lift well performance property in the system 1 comprising gas lift wells 2a-2g coupled to the common production line 3 and the common lift gas line 4 includes various steps S1 to S4. Each gas lift well can be opened for permitting production from the well or shut for preventing or stopping production from the well.

At S1, lift gas and inserted tracer gas is conveyed through the common lift gas line. The tracer gas is for example inserted intermittently at known intervals, which may facilitate analysis of returns in the production line.

At S2, fluid is produced from each of the gas lift wells 2a-2g, constituting a first plurality of gas lift wells. Lift gas enters the production tubing at one or more downhole locations along the production tubing 31 in each of the plurality of gas lift wells 2a-2g. Gas lift production fluid is conveyed from the plurality of gas lift wells through the common production line 3. This gas lift production fluid typically includes fluid from the reservoir, lift gas, and tracer gas from each well. The gas lift production fluid contained in the common production line 3 is commingled and combined production fluid from the plurality of producing gas lift wells 2a-2g.

At S3, the tracer gas in the gas lift production fluid from the producing wells of S2 in the common production line is detected and a first tracer gas composition response obtained. The first gas composition response comprises for example measurements of amounts or concentration of a detected tracer gas in the gas lift production fluid over time.

At S4, fluid from a plurality of the gas lift wells but not all of the gas lift wells 2a-2g is produced, constituting a second plurality of gas lift wells. This second plurality however excludes at least one gas lift well of the first plurality of gas lift wells. The gas lift well that to be excluded is determined as required. The well selected for exclusion is for example one for which the well performance property is desired to be determined. The gas lift well is excluded typically by shutting the well. Apart from the one that is excluded, this second plurality of gas lift wells includes the other gas lift wells of the first plurality, and gas lift production fluid is produced through each of these other gas lift wells. Lift gas enters the production tubing at one or more downhole locations along the production tubing in each of the second plurality of gas lift wells, and gas lift production fluid from the producing wells combined is conveyed from the second plurality of wells through the common production line. Again, the gas lift production fluid typically includes fluid from the reservoir, lift gas, and tracer in varying amounts from each well of the producing wells. The gas lift production fluid contained in the common production line is commingled and combined production fluid from the plurality of producing gas lift wells of the second plurality.

At S5, the tracer gas in the gas lift production fluid from the producing wells of S4 in the common production line is detected and a second gas composition response obtained. The tracer gas is typically a gas of a particular composition, typically nitrogen. The second gas composition response comprises for example measurements of amounts or concentration of a detected tracer gas in the gas lift production fluid over time.

At S6, the first and second gas composition responses are used to determine the gas lift performance property for an individual one or subsets of the wells. For example, a difference response is obtainable from the first and second gas

composition responses in order to determine the property for the excluded well or wells. The steps S4 and S5 can be repeated for further plurality where a different well is excluded. The gas lift performance property is for example a lift gas entry location, gas lift rate, gas lift anomalies. Identification of faults may be determined. The gas lift performance property and/or gas composition responses from different pluralities of wells are used for example to check that the gas lift is performing as intended and/or expected. For example, a fault or condition of the one or more gas lift wells and/or of components such as gas lift valves on the production tubing can be identified from the data. For example, a response anomaly correlating with lift gas entering the production at a depth where there is expected might indicate an integrity failure in the production tubing. Examples of use are indicated in Figure 4.

Various modifications and improvements may be made without departing from the scope of the invention herein described. In variants, the common lift gas line 4 is not required and instead the gas can be supplied in separate lines to the individual wells.

Whilst some of the examples above are based on detecting the presence and concentration of tracer gas in the production fluid, in other examples, one or more other constituents of the production fluid in the production line can be detected and monitored and may relate to the amounts of tracer gas entering the producing wells.

CLAIMS

1. A method of determining at least one gas lift performance property for one or more wells of a group of gas lift wells coupled to a common production line, the method comprising the steps of:

(a) producing fluid from a first plurality of gas lift wells of said group, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the production tubing in each of the first plurality of gas lift wells, conveying first gas lifted production fluid from the first plurality of gas lift wells through the common production line;

(b) using at least one fluid composition detector, obtaining a first fluid composition response associated with the first gas lifted production fluid in the common production line;

(c) producing fluid from a second plurality of gas lift wells of said group, the second plurality of gas lift wells including at least two gas lift wells of the first plurality of gas lift wells and excluding at least one gas lift well of the first plurality of gas lift wells, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the production tubing in each of the second plurality of gas lift wells, conveying second gas lifted production fluid from the second plurality through the common production line;

(d) using at least one fluid composition detector, obtaining a second fluid composition response associated with the second gas lifted production fluid in the common production line; and

(e) using the first and second responses to determine the gas lift performance property for the one or more wells of the group.

2. A method as claimed in claim 1, wherein the second plurality excludes one gas lift well of the first plurality and includes each of the other gas lift wells of the first plurality.

3. A method as claimed in claim 1, wherein the second plurality excludes two gas lift wells of the first plurality and includes each of the other gas lift wells of the first plurality.

4. A method as claimed in claim 1 or 2, which further comprises:

producing fluid from a further plurality of gas lift wells, the further plurality excluding another gas lift well of the first plurality and including each of the other gas lift wells of the first plurality, lift gas and inserted tracer fluid entering the production tubing at one or more downhole locations along the production tubing in each of the further plurality of gas lift wells, conveying gas lifted production fluid from the further plurality through the common production line, using at least one fluid composition detector, obtaining a further fluid composition response associated with the production fluid in the common production line, and further using the further response to determine the gas lift performance property.

5. A method as claimed in claim 4, wherein the production of fluid from the further plurality of gas lift wells and the obtaining of the further response is performed with a different well excluded and repeated until each of the wells of the first plurality has been excluded.

6. A method as claimed in any preceding claim, wherein step (e) is performed to determine the gas lift performance property for the excluded well.

7. A method as claimed in any preceding claim, wherein step (e) includes identifying one or more differences between the first and second responses and based on the one or more differences determining the gas lift performance property.

8. A method as claimed in claim 6, which further comprises comparing the responses to identify one or more differences.

9. A method as claimed in any preceding claim, which further comprises using the determined gas lift performance property to determine a fault or condition of the one or more gas lift wells and/or one or more components thereof.

10. A method as claimed in any preceding claim, which includes shutting the well to be excluded from the second plurality.

11. A method as claimed in any preceding claim, which includes performing step (a) before step (c) or vice versa.

12. A method of determining at least one gas lift performance property in a system in which a plurality of gas lift wells are coupled to a common production line, the method comprising the steps of:

(p) producing fluid from a first gas lift well, a second gas lift well, and a third gas lift well of said plurality, lift gas and inserted tracer entering the production tubing at one or more downhole locations along the production tubing in each of the first, second, and third gas lift wells, conveying combined gas lift production fluid from the first, second, and third gas lift wells through the common production line, and using at least one fluid composition detector, obtaining a first fluid composition response associated with the fluid in the common production line;

(q) producing fluid from the first gas lift well and the second gas lift well, third gas lift well being shut, lift gas and inserted tracer entering the production tubing at one or more downhole locations along the production tubing in each of the first and second gas lift wells, conveying combined gas lifted production fluid from the first and second gas lift wells through the common production line, and using at least one fluid composition detector, obtaining a second fluid composition response associated with the fluid in the common production line; and

(r) using the first and second responses to determine the gas lift performance property for one or more of the first, second, and third gas lift wells.

13. A method as claimed in claim 12, which further comprises the step of:

(s) producing fluid from the first gas lift well and the third gas lift well, the second gas lift well being shut, lift gas and inserted tracer entering the production tubing at one or more downhole locations along the production tubing in each of the first and third gas lift wells, conveying combined gas lifted production fluid from the first and third gas lift wells through the common production line, using at least one fluid composition detector, obtaining a third fluid composition response associated with the fluid in the common production line, for the first and third gas lift wells combined; and

wherein step (r) includes further using the third response to determine the gas lift performance property for the one or more of the first, second, and third gas lift wells.

14. A method as claimed in claim 12 or 13, which further comprises the step of:

(t) producing fluid from the second gas lift well and the third gas lift well, the first gas lift well being shut, lift gas and inserted tracer entering the production tubing at one or more downhole locations along the production tubing in each of the second and third gas lift wells, conveying combined gas lifted production fluid from the second and third gas lift wells through the common production line, using at least one fluid composition detector, obtaining a fourth fluid composition response associated with the fluid in the common production line, for the second and third gas lift wells combined; and

wherein step (r) includes further using the fourth response to determine the gas lift performance property for the one or more of the first, second, and third gas lift wells.

15. A method as claimed in any preceding claim, which includes injecting tracer fluid into at least one lift gas supply line and supplying the lift gas and inserted tracer to the producing gas lift wells.

16. A method as claimed in claim 13, wherein the injection of the tracer fluid is performed intermittently.

17. A method as claimed in any preceding claim, wherein the tracer fluid comprises tracer gas.

18. A method as claimed in claim 17, wherein the tracer gas is nitrogen gas.

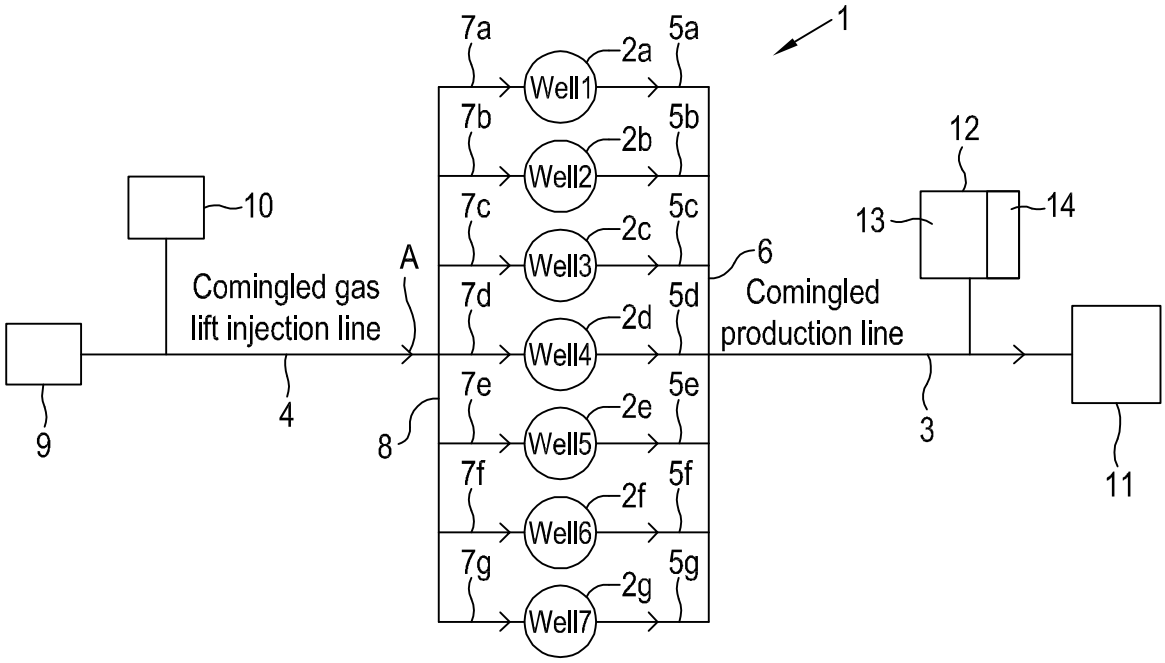
19. A method as claimed in any preceding claim, wherein the fluid composition response comprises tracer fluid concentration data.

20. A method as claimed in any preceding claim, wherein the fluid composition detector comprises a tracer fluid detector.

21. Apparatus for determining at least one gas lift performance property for one or more wells of a group of gas lift wells coupled to a common production line, the apparatus comprising:

at least one fluid composition detector for obtaining fluid composition data associated with fluid received in the common production line from the gas lift wells; and

determiner means configured to receive fluid composition data from the detector, the determiner being further configured to determine the gas lift performance property based upon first fluid composition data from the production of gas lift production fluid from the first plurality of gas lift wells and second fluid composition data from the production of gas lift production fluid from the second plurality of wells.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Well6
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2g
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FIG. 1

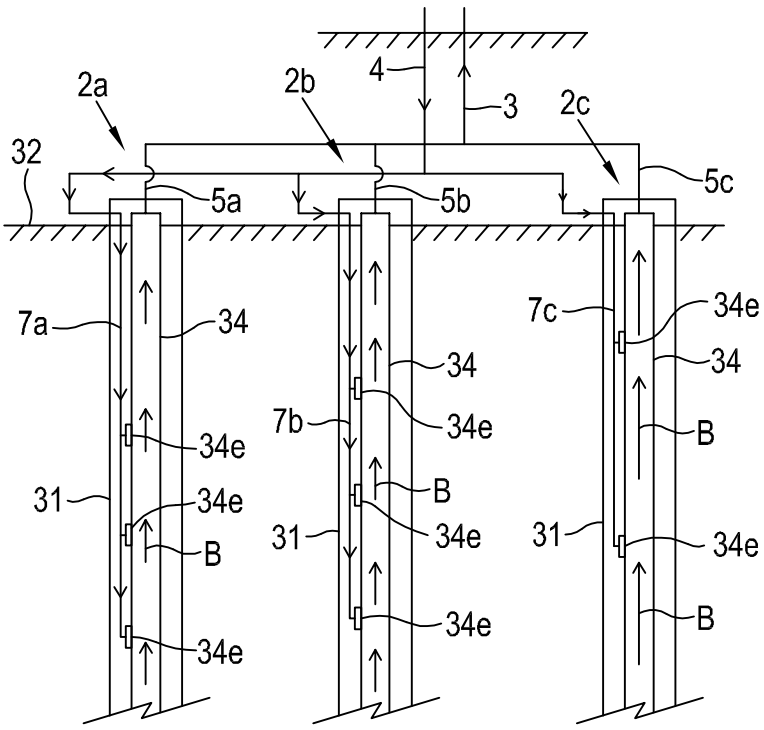
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FIG. 2

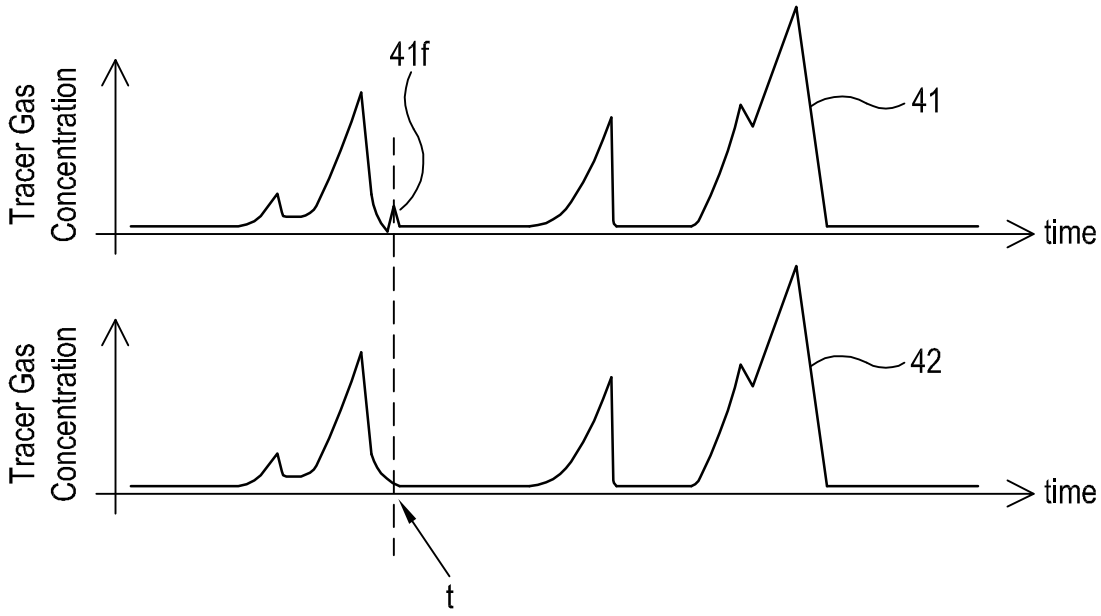
Tracer Gas Concentration
41f
41
time
Tracer Gas Concentration
42
time
t

FIG. 3

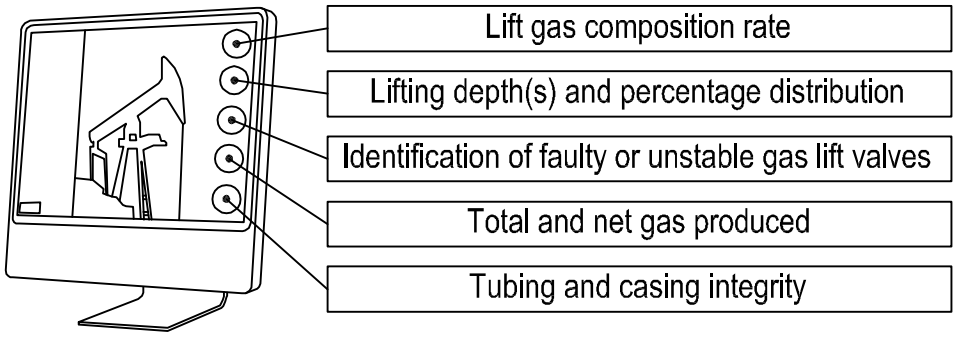
Lift gas composition rate
Lifting depth(s) and percentage distribution
Identification of faulty or unstable gas lift valves
Total and net gas produced
Tubing and casing integrity

FIG. 4