

within the mandrel allow the gas to be introduced into the fluid flow within the production tubing. GL systems help lift the product to the surface by reducing the density of the fluid (and thus the downhole pressure), which accelerates the movement of fluids from the formation through the perforations in the casing and up the production tubing.

5 Downhole sensors, if installed, collect and transmit data to the surface (e.g., via cables to the surface and/or wirelessly). The data may include, but is not limited to, injected gas lift pressure and temperature, and produced fluid pressure and temperature. Although the data provided enables monitoring of the performance of a GL system, determining the underlying cause of a failure or a variation in the performance of GL system is a more complicated task.
10 A given GL system failure or performance variation can have numerous causes and operators strive to identify the cause of such issues quickly to reduce any resulting downtime or reduced production. While experienced petroleum/well surveillance personnel may rely on their personal experience to diagnose and resolve such issues, a more automated approach based on a broader information base offers the possibility of diagnosing issues and providing
15 more optimal solutions in a shorter period of time.

SUMMARY

According to an aspect of the present invention, there is provided a method for monitoring, diagnosing and optimizing operation of a gas lift (GL) system that comprises:
20 collecting measured data representative of a state of a GL system within a well, and further storing the measured data; comparing the measured data to calculated data generated by a model of the well; identifying one or more likely conditions of the GL system based at least in part on mismatches between the measured data and the calculated data; updating the well
25 model to reflect the one or more likely conditions and one or more user-selected corrections to the one or more likely conditions; generating a plurality of GL system performance curves using the updated well model; ~~and~~ presenting to a user one or more actions recommended to achieve a GL system performance consistent with a GL system operating point on at least one of the plurality of GL system performance curves; accepting a user selection of one of the one or more actions recommended to achieve the GL system performance consistent with the GL
30 system operating point; and initiating a change to one or more GL system settings in response to the accepting of the user selection.

According to another aspect of the present invention, there is provided a gas lift (GL) monitoring, diagnosing and optimizing system that comprises: a memory having GL system monitoring, diagnosing and optimizing software; and one or more processors coupled to the memory, the software causing the one or more processors to:

5 collect measured data representative of a state of a GL system within a well, and further store the measured data; compare the measured data to calculated data generated by a model of the well; identify one or more likely conditions of the GL system based at least in part on mismatches between the measured data and the calculated data; update the well model to reflect the one or more likely conditions and one or more user-selected corrections to the one
10 or more likely conditions; generate a plurality of GL system performance curves using the updated well model; ~~and~~ present to a user one or more actions recommended to achieve a GL system performance consistent with a GL system operating point on at least one of the plurality of GL system performance curves; accept a user selection of one of the one or more actions recommended to achieve the GL system performance consistent with the GL system
15 operating point; and initiating a change to one or more GL system settings in response to the accepting of the user selection.

According to another aspect of the present invention, there is provided a non-transitory information storage medium having gas lift (GL) system monitoring, diagnosing and
20 optimizing software that comprises: a data collection and storage module that collects measured data representative of a state of a GL system within a well, and further stores the measured data; a comparison module that compares the measured data to calculated data generated by a model of the well; a condition identifier module that identifies one or more likely conditions of the GL system based at least in part on mismatches between the
25 measured data and the calculated data; a model update module that updates the well model to reflect the one or more likely conditions and one or more user-selected corrections to the one or more likely conditions; a performance curve module that generates a plurality of GL system performance curves using the updated well model; ~~and~~ a recommended action module that presents to a user one or more actions recommended to achieve a GL system
30 performance consistent with a GL system operating point on at least one of the plurality of GL system performance curves, accept a user selection of one of the one or more actions recommended to achieve the GL system performance consistent with the GL system operating point, and initiate a change to one or more GL system settings in response to accepting of the user selection.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the various disclosed embodiments can be obtained when the following detailed description is considered in conjunction with the attached drawings, in
5 which:

FIG. 1A shows a production well that sources measured well and gas lift (GL) system data.

FIG. 1B shows a simplified diagram of an illustrative GL system.

FIGS. 2A-2D show illustrative user interface displays for monitoring, diagnosing and
10 optimizing GL operations.

FIG. 3 shows an illustrative data acquisition and processing system suitable for implementing software-based embodiments of the systems and methods described herein.

FIG. 4A shows an illustrative GL system monitoring, diagnosing and optimizing method.

15 FIG. 4B shows an illustrative GL operations task ticketing method that works in conjunction with the illustrative GL system monitoring, diagnosing and optimizing method described.

CLAIMS

WHAT IS CLAIMED IS:

1. A method for monitoring, diagnosing and optimizing operation of a gas lift (GL) system that comprises:
 - collecting measured data representative of a state of a GL system within a well, and further storing the measured data;
 - comparing the measured data to calculated data generated by a model of the well;
 - identifying one or more likely conditions of the GL system based at least in part on mismatches between the measured data and the calculated data;
 - updating the well model to reflect the one or more likely conditions and one or more user-selected corrections to the one or more likely conditions;
 - generating a plurality of GL system performance curves using the updated well model;
 - presenting to a user one or more actions recommended to achieve a GL system performance consistent with a GL system operating point on at least one of the plurality of GL system performance curves;
 - accepting a user selection of one of the one or more actions recommended to achieve the GL system performance consistent with the GL system operating point; and
 - initiating a change to one or more GL system settings in response to the accepting of the user selection.
2. The method of claim 1, wherein identifying the one or more likely conditions comprises comparing the measured data to a database of known GL system states.
3. The method of claim 1, wherein the measured data comprises data selected from the group consisting of real-time data, recorded data and simulated data.
4. The method of claim 1, wherein the data representative of the state of the GL system comprises data selected from the group consisting of bottom hole pressure, bottom hole temperature, tube head pressure, tube head temperature, choke size, fluid flow rates, oil

flow rates and water cuts, gas/liquid ratios, injected gas pressure, injected gas temperature, injected gas flow rate and one or more mandrel valve settings.

5. The method of claim 1, further comprising:
 - generating an advisory message if a value of the measured data is detected outside of an allowable range of values and sending out a corresponding notification to one or more contacts of a distribution list;
 - creating a task tracking ticket corresponding to the advisory message;
 - updating the task tracking ticket to include the action recommended and personnel assigned to implement the solution;
 - updating the task tracking ticket to document implementation of the solution and closing the task tracking ticket; and
 - generating an additional advisory message and sending out an additional corresponding notification to the one or more contacts each time the task tracking ticket is updated.
6. The method of claim 5, further comprising presenting to at least one of one or more users the current status of the task tracking ticket.
7. The method of claim 5, further comprising determining if at least one of one or more users may view or update the task tracking ticket based upon an access permission structure.
8. A gas lift (GL) monitoring, diagnosing and optimizing system that comprises:
 - a memory having GL system monitoring, diagnosing and optimizing software; and
 - one or more processors coupled to the memory, the software causing the one or more processors to:
 - collect measured data representative of a state of a GL system within a well, and further store the measured data;
 - compare the measured data to calculated data generated by a model of the well;
 - identify one or more likely conditions of the GL system based at least in part on mismatches between the measured data and the calculated data;
 - update the well model to reflect the one or more likely conditions and one or more user-selected corrections to the one or more likely conditions;
 - generate a plurality of GL system performance curves using the updated well model;

present to a user one or more actions recommended to achieve a GL system performance consistent with a GL system operating point on at least one of the plurality of GL system performance curves;
accept a user selection of one of the one or more actions recommended to achieve the GL system performance consistent with the GL system operating point; and
initiating a change to one or more GL system settings in response to the accepting of the user selection.

9. The system of claim 8, wherein the software further implements a rule-based expert system that identifies the one or more likely conditions at least in part by comparing the measured data to a database of known GL system states.
10. The system of claim 8, wherein the measured data comprises data selected from the group consisting of real-time data, recorded data and simulated data.
11. The system of claim 8, wherein the data representative of the state of the GL system comprises data selected from the group consisting of bottom hole pressure, bottom hole temperature, tube head pressure, tube head temperature, choke size, fluid flow rates, oil flow rates and water cuts, gas/liquid ratios, injected gas pressure, injected gas temperature, injected gas flow rate and one or more mandrel valve settings.
12. The system of claim 8, wherein the software further causing the one or more processors to:
 - generate an advisory message if a value of the measured data is detected outside of an allowable range of values and send out a corresponding notification to one or more contacts of a distribution list;
 - create a task tracking ticket corresponding to the advisory message;
 - update the task tracking ticket to include the action recommended and personnel assigned to implement the solution;
 - update the task tracking ticket to document implementation of the solution and close the task tracking ticket; and

generate an additional advisory message and send out an additional corresponding notification to the one or more contacts each time the task tracking ticket is updated.

13. A non-transitory information storage medium having gas lift (GL) system monitoring, diagnosing and optimizing software that comprises:
 - a data collection and storage module that collects measured data representative of a state of a GL system within a well, and further stores the measured data;
 - a comparison module that compares the measured data to calculated data generated by a model of the well;
 - a condition identifier module that identifies one or more likely conditions of the GL system based at least in part on mismatches between the measured data and the calculated data;
 - a model update module that updates the well model to reflect the one or more likely conditions and one or more user-selected corrections to the one or more likely conditions;
 - a performance curve module that generates a plurality of GL system performance curves using the updated well model; and
 - a recommended action module that presents to a user one or more actions recommended to achieve a GL system performance consistent with a GL system operating point on at least one of the plurality of GL system performance curves, accept a user selection of one of the one or more actions recommended to achieve the GL system performance consistent with the GL system operating point, and initiate a change to one or more GL system settings in response to accepting of the user selection.
14. The storage medium of claim 13, wherein the condition identifier module comprises rule-based expert system software that identifies the one or more likely conditions at least in part by comparing the measured data to a database of known GL system states.

15. The storage medium of claim 13, wherein the measured data comprises data selected from the group consisting of real-time data, recorded data and simulated data.
16. The storage medium of claim 13, wherein the data representative of the state of the GL system comprises data selected from the group consisting of bottom hole pressure, bottom hole temperature, tube head pressure, tube head temperature, choke size, fluid flow rates, oil flow rates and water cuts, gas/liquid ratios, injected gas pressure, injected gas temperature, injected gas flow rate and one or more mandrel valve settings.
17. The storage medium of claim 13, wherein the software further comprises a task ticket module that:
 - generates an advisory message if a value of the measured data is detected outside of an allowable range of values and sends out a corresponding notification to one or more contacts of a distribution list;
 - creates a task tracking ticket corresponding to the advisory message;
 - updates the task tracking ticket to include the action recommended and personnel assigned to implement the solution;
 - updates the task tracking ticket to document implementation of the solution and closes the task tracking ticket; and
 - generates an additional advisory message and sends out an additional corresponding notification to the one or more contacts each time the task tracking ticket is updated.

CLAIMS

WHAT IS CLAIMED IS:

1. A method for monitoring, diagnosing and optimizing operation of a gas lift (GL) system that comprises:
 - collecting measured data representative of a state of a GL system within a well, and further storing the measured data;
 - comparing the measured data to calculated data generated by a model of the well;
 - identifying one or more likely conditions of the GL system based at least in part on mismatches between the measured data and the calculated data;
 - updating the well model to reflect the one or more likely conditions and one or more selected corrections to the one or more likely conditions;
 - generating a plurality of GL system performance curves using the updated well model;
 - presenting to a user one or more actions recommended to achieve a GL system performance consistent with a GL system operating point on at least one of the plurality of GL system performance curves;
 - accepting a user selection of one of the one or more actions recommended to achieve the GL system performance consistent with the GL system operating point; and
 - initiating a change to one or more GL system settings in response to the accepting of the user selection.
2. The method of claim 1, wherein identifying the one or more likely conditions comprises comparing the measured data to a database of known GL system states.
3. The method of claim 1, wherein the measured data comprises data selected from the group consisting of real-time data, recorded data and simulated data.
4. The method of claim 1, wherein the data representative of the state of the GL system comprises data selected from the group consisting of bottom hole pressure, bottom hole temperature, tube head pressure, tube head temperature, choke size, fluid flow rates, oil

flow rates and water cuts, gas/liquid ratios, injected gas pressure, injected gas temperature, injected gas flow rate and one or more mandrel valve settings.

5. The method of claim 1, further comprising:
 - generating an advisory message if a value of the measured data is detected outside of an allowable range of values and sending out a corresponding notification to one or more contacts of a distribution list;
 - creating a task tracking ticket corresponding to the advisory message;
 - updating the task tracking ticket to include the action recommended and personnel assigned to implement the solution;
 - updating the task tracking ticket to document implementation of the solution and closing the task tracking ticket; and
 - generating an additional advisory message and sending out an additional corresponding notification to the one or more contacts each time the task tracking ticket is updated.
6. The method of claim 5, further comprising presenting to at least one of one or more users the current status of the task tracking ticket.
7. The method of claim 5, further comprising determining if at least one of one or more users may view or update the task tracking ticket based upon an access permission structure.
8. A gas lift (GL) monitoring, diagnosing and optimizing system that comprises:
 - a memory having GL system monitoring, diagnosing and optimizing software; and
 - one or more processors coupled to the memory, the software causing the one or more processors to:
 - collect measured data representative of a state of a GL system within a well, and further store the measured data;
 - compare the measured data to calculated data generated by a model of the well;
 - identify one or more likely conditions of the GL system based at least in part on mismatches between the measured data and the calculated data;
 - update the well model to reflect the one or more likely conditions and one or more selected corrections to the one or more likely conditions;
 - generate a plurality of GL system performance curves using the updated well model;

present to a user one or more actions recommended to achieve a GL system performance consistent with a GL system operating point on at least one of the plurality of GL system performance curves;
accept a user selection of one of the one or more actions recommended to achieve the GL system performance consistent with the GL system operating point; and
initiating a change to one or more GL system settings in response to the accepting of the user selection.

9. The system of claim 8, wherein the software further implements a rule-based expert system that identifies the one or more likely conditions at least in part by comparing the measured data to a database of known GL system states.
10. The system of claim 8, wherein the measured data comprises data selected from the group consisting of real-time data, recorded data and simulated data.
11. The system of claim 8, wherein the data representative of the state of the GL system comprises data selected from the group consisting of bottom hole pressure, bottom hole temperature, tube head pressure, tube head temperature, choke size, fluid flow rates, oil flow rates and water cuts, gas/liquid ratios, injected gas pressure, injected gas temperature, injected gas flow rate and one or more mandrel valve settings.
12. The system of claim 8, wherein the software further causing the one or more processors to:
 - generate an advisory message if a value of the measured data is detected outside of an allowable range of values and send out a corresponding notification to one or more contacts of a distribution list;
 - create a task tracking ticket corresponding to the advisory message;
 - update the task tracking ticket to include the action recommended and personnel assigned to implement the solution;
 - update the task tracking ticket to document implementation of the solution and close the task tracking ticket; and

generate an additional advisory message and send out an additional corresponding notification to the one or more contacts each time the task tracking ticket is updated.

13. A non-transitory information storage medium having gas lift (GL) system monitoring, diagnosing and optimizing software that comprises:
 - a data collection and storage module that collects measured data representative of a state of a GL system within a well, and further stores the measured data;
 - a comparison module that compares the measured data to calculated data generated by a model of the well;
 - a condition identifier module that identifies one or more likely conditions of the GL system based at least in part on mismatches between the measured data and the calculated data;
 - a model update module that updates the well model to reflect the one or more likely conditions and one or more selected corrections to the one or more likely conditions;
 - a performance curve module that generates a plurality of GL system performance curves using the updated well model; and
 - a recommended action module that presents to a user one or more actions recommended to achieve a GL system performance consistent with a GL system operating point on at least one of the plurality of GL system performance curves, accept a user selection of one of the one or more actions recommended to achieve the GL system performance consistent with the GL system operating point, and initiate a change to one or more GL system settings in response to accepting of the user selection.
14. The storage medium of claim 13, wherein the condition identifier module comprises rule-based expert system software that identifies the one or more likely conditions at least in part by comparing the measured data to a database of known GL system states.

15. The storage medium of claim 13, wherein the measured data comprises data selected from the group consisting of real-time data, recorded data and simulated data.
16. The storage medium of claim 13, wherein the data representative of the state of the GL system comprises data selected from the group consisting of bottom hole pressure, bottom hole temperature, tube head pressure, tube head temperature, choke size, fluid flow rates, oil flow rates and water cuts, gas/liquid ratios, injected gas pressure, injected gas temperature, injected gas flow rate and one or more mandrel valve settings.
17. The storage medium of claim 13, wherein the software further comprises a task ticket module that:
 - generates an advisory message if a value of the measured data is detected outside of an allowable range of values and sends out a corresponding notification to one or more contacts of a distribution list;
 - creates a task tracking ticket corresponding to the advisory message;
 - updates the task tracking ticket to include the action recommended and personnel assigned to implement the solution;
 - updates the task tracking ticket to document implementation of the solution and closes the task tracking ticket; and
 - generates an additional advisory message and sends out an additional corresponding notification to the one or more contacts each time the task tracking ticket is updated.