United States Patent	12385367
Kind Code	B2
Date of Patent	August 12, 2025
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Monitoring well conditions across liner hanger packers

Abstract

A well tool assembly to monitor conditions across a liner hanger packer includes a liner hanger to support a well liner. A liner packer, which includes a seal element, two sensor sub-assemblies and a controller, is coupled to the liner hanger. The seal element is on an outer surface of the liner packer and can fluidically seal the outer surface of the liner packer to the inner surface of the tubular. The first sensor sub-assembly and the second sensor sub-assembly are attached to the outer surface of the liner packer on either side of the seal element. Each sensor sub-assembly can, respectively, sense well properties on the side of the seal element on which the sub-assembly is attached. The controller is operatively coupled to the two sensor sub-assemblies, and can receive sensed well properties from the two sensor sub-assemblies, and transmit the received sensed well properties to a receiver.

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Appl. No.: **18/326357**

Filed: **May 31, 2023**

Prior Publication Data

Document Identifier	Publication Date
US 20240401439 A1	Dec. 05, 2024

Publication Classification

Int. Cl.: **E21B43/10** (20060101); **E21B47/06** (20120101); **E21B47/07** (20120101); **E21B47/10** (20120101); **E21B47/12** (20120101)

U.S. Cl.:

CPC **E21B43/10** (20130101); **E21B47/06** (20130101); **E21B47/07** (20200501); **E21B47/10** (20130101); **E21B47/12** (20130101);

Field of Classification Search

CPC: E21B (43/10); E21B (47/06); E21B (47/07); E21B (47/12)

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Background/Summary

TECHNICAL FIELD

(1) This disclosure relates to operations involving a well, for example, one through which hydrocarbons can be produced, including, for example, well construction operations and well production operations.

BACKGROUND

(2) Hydrocarbon wells have casing strings, or liners, installed prior to penetrating a subterranean zone to a subsurface reservoir and beginning production of hydrocarbons (petroleum, natural gas, combinations of them). Such casing strings provide weight hanging capability and pressure zonal isolation. In some instances, more than one casing string can be run. In such instances, the first casing string, installed at the top of the well, has the largest diameter. Thereafter, a subsequent casing string is placed into the well by passing it through the already installed first casing string. A liner (or liner string) is installed within a casing string to flow fluids (e.g., drilling mud, casing cement, or other fluids) from a surface of the well to downhole locations in the well. A liner hanger is a well tool that is used to install (i.e., hang) the liner from the downhole end of the casing string.

SUMMARY

(3) This specification describes technologies relating to monitoring well conditions across liner

hanger packers.

(4) Certain aspects of the subject matter described here can be implemented as a well tool assembly. The assembly includes a liner hanger that can support a liner within a well. The liner hanger can be supported by a tubular installed within the well. A liner packer is coupled to the liner hanger. The liner packer can fluidically seal an outer surface of the liner hanger to an inner surface of the tubular. The liner packer includes a seal element, two sensor sub-assemblies and a controller. The seal element is on an outer surface of the liner packer and can fluidically seal the outer surface of the liner packer to the inner surface of the tubular. The first sensor sub-assembly is attached to the outer surface of the liner packer on a first portion of the liner packer between the seal element and a first end of the liner packer. The first sensor sub-assembly can sense well properties in a first space between the outer space of the liner packer and the inner surface of the tubular. The second sensor sub-assembly is attached to the outer surface of the liner packer on a second portion of the liner packer between the seal element and a second end of the liner packer. The second end is opposite the first end. The second sensor sub-assembly can sense well properties in a second space between the outer surface of the liner packer and the inner surface of the tubular. The controller is operatively coupled to the two sensor sub-assemblies. The controller includes one or more processors and a computer-readable medium storing instructions executable by the one or more processors to perform operations that include receiving sensed well properties from the two sensor sub-assemblies, and transmitting the received sensed well properties to a receiver.

(5) An aspect combinable with any other aspect includes the following features. When the assembly is installed within the well, the first portion is uphole of the liner packer, and the second portion is downhole of the liner packer.

(6) An aspect combinable with any other aspect includes the following features. The seal element can fluidically isolate the first portion from the second portion.

(7) An aspect combinable with any other aspect includes the following features. Each of the first sensor sub-assembly and the second sensor sub-assembly, respectively, includes a pressure sensor configured to sense a pressure in the first portion and the second portion, respectively, and a temperature sensor configured to sense a temperature in the first portion and the second portion, respectively.

(8) An aspect combinable with any other aspect includes the following features. The controller is attached to the first portion of the liner packer.

(9) An aspect combinable with any other aspect includes the following features. The second sensor sub-assembly can transmit the sensed well properties to the controller across the seal element.

(10) An aspect combinable with any other aspect includes the following features. The receiver can wirelessly receive the sensed well properties from the two sensor sub-assemblies.

(11) An aspect combinable with any other aspect includes the following features. A liner tieback receptacle is positioned between the liner hanger and the liner packer. The liner tieback receptacle can receive an end of the liner to form a fluidically sealed conduit from the liner through the liner hanger.

(12) Certain aspects of the subject matter described here can be implemented as a method. A well tool assembly is formed by attaching a seal element to an outer surface of a liner packer. The seal element can fluidically seal the outer surface of the liner packer to an inner surface of a tubular in which the liner packer is configured to be installed. A first sensor sub-assembly is attached to the outer surface of the liner packer on a first portion of the liner packer between the seal element and a first end of the liner packer. A second sensor sub-assembly is attached to the outer surface of the liner packer on a second portion of the liner packer between the seal element and a second end of the liner packer, the second end opposite the first end. A controller is attached on the outer surface of the liner packer on the first portion. The controller can receive sensed well properties from the first sensor sub-assembly and the second sensor sub-assembly. A liner hanger is coupled to the liner packer. The liner hanger can support a liner within the well. The liner hanger is supported by the

tubular. The well tool assembly is run into and set at a downhole location in a well. The well properties sensed by the first sensor sub-assembly and the second sensor sub-assembly are periodically received at a surface of the well from the controller.
(13) An aspect combinable with any other aspect includes the following features. After running the well tool assembly into and setting the well tool assembly at the downhole location in the well, the first portion is uphole of the liner packer, and the second portion is downhole of the liner packer. The first portion is fluidically isolated from the second portion.
(14) An aspect combinable with any other aspect includes the following features. Each of the first sensor sub-assembly and the second sensor sub-assembly, respectively, includes a pressure sensor configured to sense a pressure in the first portion and the second portion and a temperature sensor configured to sense a temperature in the first portion and the second portion. Each pressure sensor senses the pressure in the first portion and the second portion, respectively. Each temperature sensor senses the temperature in the first portion and the second portion, respectively.
(15) An aspect combinable with any other aspect includes the following features. Based on the well properties received at the surface, a change in the well properties sensed by the second sensor sub-assembly are determined. In response to the determining, corrective well operations are performed.
(16) An aspect combinable with any other aspect includes the following features. The change in the well properties includes a change in the pressure sensed by a pressure sensor. The pressure sensor is installed in an annulus between the outer surface of the liner packer and the inner surface of the tubular.
(17) An aspect combinable with any other aspect includes the following features. The change in the well properties includes a change in the temperature sensed by a temperature sensor. The temperature sensor is installed in an annulus between the outer surface of the liner packer and the inner surface of the tubular.
(18) An aspect combinable with any other aspect includes the following features. The corrective well operations include ceasing well operations until the corrective well operations have been completed.
(19) The details of one or more implementations of the subject matter described in this specification are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages of the subject matter will become apparent from the description, the drawings, and the claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a schematic diagram of an example of a well in which an implementation of a well tool assembly is installed.
(2) FIG. **2** is a schematic diagram of components of the well tool assembly of FIG. **1**.
(3) FIG. **3** is a schematic diagram of an example of a liner packer of the well tool assembly of FIG. **1**.
(4) FIG. **4** is a flowchart of an example of a method of implementing the well tool assembly of FIG. **1**.
(5) Like reference numbers and designations in the various drawings indicate like elements.
DETAILED DESCRIPTION
(6) FIG. **1** is a schematic diagram of an example of a well **100** in which an implementation of a well tool assembly **102** is installed. The well **100** is formed from a surface **104** through a subterranean zone **106** (e.g., a formation, a portion of a formation, multiple formations) to a subsurface reservoir (not shown) in which hydrocarbons are trapped. A casing string (or casing) **108** is run into and set (e.g., cemented) within the well **100**. In some implementations, only one

casing string **108** can be used. In some implementations, multiple casing strings, each of successively smaller diameters, can be run into the well **100**.

(7) The well tool assembly **102** is used to hang a liner **110** from the downhole end of the casing string **108**. For example, the liner **110** can be a casing string that runs downhole of the casing string **108**. Alternatively, the liner **110** can be a production tubing that runs from the downhole end of the casing string **108** to the subsurface reservoir and into which hydrocarbons from the subsurface reservoir flow. In general, the liner **110** can be any tubular that can be used in a well operation.

(8) As described below with reference to the following figures, the well tool assembly **102** can be run into and set in the well **100** at a downhole location in the well **100**. The well tool assembly **100** can provide structural support during well construction as well as over the life of the well **100**. In addition, and either during well construction or during well operation (e.g., hydrocarbon production) or both, the well tool assembly **102** isolates downhole fluids and downhole pressure from coming up the well **100** during the well life time. In addition, the well tool assembly **102** can periodically measure well properties (e.g., pressure, temperature, other well properties) both uphole and downhole of the downhole location at which the well tool assembly **102** is installed. The well tool assembly **102** can communicate the measured well properties to the surface **104** (e.g., to control equipment at the surface **104**).

(9) FIG. **2** is a schematic diagram of components of the well tool assembly **102** (FIG. **1**). The assembly **102** includes a liner hanger **202** and a liner packer **204** coupled to the liner hanger **202**. The liner hanger **202** can support a liner (e.g., the liner **110**) within the well **100** (FIG. **1**). The liner hanger **202** can also be supported by a tubular (e.g., the casing **108** within the well **100**. The liner hanger **202** provides structural support to the well **100** during well construction and during well operation over the life of the well **100**. The liner hanger **202** attaches to an inner surface of a string previously installed within the well **100**, e.g., the inner wall of the casing **108**. For example, the liner hanger **202** can be hung, i.e., connected to the casing **108**, by setting slips that grip against the inner wall of the casing **108**. In another example, the liner hanger **202** can be an expandable hanger hung by external expansion of the liner hanger **202** against the inner wall of the casing **108**.

(10) In some implementations, the assembly **102** includes a liner tieback receptacle **206** connected to the liner hanger **202** and positioned between the liner hanger **202** and the liner packer **204**. The liner tieback receptacle **206** enables the base of a tubular (e.g., production tubing) to be stabbed into the liner top, providing both a seal and a continuous conduit for produced fluids. For example, the liner tieback receptacle **206** can receive the end of the liner **110** and form the fluidically sealed conduit from the liner **110** through the liner hanger **202**.

(11) The liner packer **204** can fluidically seal an outer surface of the liner hanger **202** to an inner surface of the tubular (e.g., the casing **108**). FIG. **3** is a schematic diagram of an example of the liner packer **204** of the well tool assembly **102** (FIG. **1**). The liner packer **204** includes a seal element **302** on an outer surface **304** of the liner packer **204**. The seal element **302** can fluidically seal the outer surface **304** of the liner packer **304** to the inner surface of the tubular (e.g., the casing **108**). For example, the seal element **302** can be an expandable seal or a static seal such as a metal-to-metal seal. The seal element **302** is positioned between the ends (a first end **306***a* and a second, opposite end **306***b*) on the outer surface **304** of the liner packer **204**. The position of the seal element **302** on the outer surface **304** separates the well **100** into a first portion **308***a* between the first end **306***a* and the seal element **302**, and a second portion **308***b* between the seal element **302** and the second end **306***b*. When the well tool assembly **102** is run into and installed in the well **100**, the first portion **308***a* can reside uphole of the seal element **302** (the uphole portion), and the second portion **308***b* can reside downhole of the seal element **302** (the downhole portion). As explained above, the liner packer **204** fluidically isolates the first portion **308***a* (e.g., the uphole portion) from the second portion **308***b* (e.g., the downhole portion).

(12) The liner packer **204** includes a first sensor sub-assembly **310***a* attached to the outer surface **304** of the liner packer **204** on the first portion **308***a* of the liner packer **204**. The first sensor sub-

assembly **310***a* can sense well properties in a first space between the outer surface **304** of the liner packer **204** and the inner surface of the tubular (e.g., the inner wall of the casing **108**), specifically in the first portion **308***a* of the well **100**. The liner packer **204** includes a second sub-assembly **310***b* attached to the outer surface **304** of the liner packer **204** on the second portion **308***b* of the liner packer **204**. The second sensor sub-assembly **310***b* can sense well properties in a second space between the outer surface **304** of the liner packer **204** and the inner surface of the tubular (e.g., the inner wall of the casing **108**), specifically in the second portion **308***b* of the well **100**.
(13) In some implementations, the first sensor sub-assembly **310***a* includes a temperature sensor **312***a* and a pressure sensor **314***a* that can sense temperature and pressure, respectively, adjacent the respective sensors in the first portion **308***a* (e.g., the uphole portion). The second sensor sub-assembly **310***b* includes a temperature sensor **312***b* and a pressure sensor **314***b* that can sense temperature and pressure, respectively, adjacent the respective sensors in the second portion **308***b* (e.g., the downhole portion). The sensor sub-assemblies can include additional or different sensors to measure well properties such as gas chromatography sensors that measure levels of different gases such as carbon (C1, C2, C3, C4, C5), hydrogen sulfide content, carbon dioxide or other gases. In this manner, the sensors in the sub-assemblies can sense well properties uphole and downhole of the well tool assembly **102** after the assembly **102** has been deployed to hang the liner **110** (FIG. **1**) downhole of the casing **108** (FIG. **1**).
(14) In some implementations, the well tool assembly **102** can be deployed as a smart component that can take action responsive to changes in the well properties on either side of the seal element **302**. To do so, the well tool assembly **102** includes a controller **316** operatively coupled to the first sensor sub-assembly **310***a* and the second sensor sub-assembly **310***b*. In some implementations, the controller **316** can be deployed as a computer system that includes one or more processors and a computer-readable medium (e.g., non-transitory computer-readable medium) storing instructions executable by the one or more processors to perform operations. The controller **316** can receive sensed well properties from the first sensor sub-assembly **310***a* and the second sensor sub-assembly **310***b*, and transmit the received sensed well properties to a receiver, e.g., a receiver deployed at the surface **104** (FIG. **1**) of the well **100**.
(15) In some implementations, the controller **316** is mounted to the liner packer **204**, e.g., on the outer surface **304** of the liner packer **204**. For example, the controller **316** can be threaded to the top of the liner packer **204**. The controller **316** can include a power source (e.g., a battery) to power the controller **316**. Alternatively, or in addition, power to the controller **316** can be provided by an electric cable run into the well **100** from the surface **104**.
(16) As shown in FIG. **3**, the controller **316** is installed on the first portion **308***a* (i.e., the uphole portion) of the liner packer **204**. Such installation can allow easier access to the controller **316** (e.g., for removal, repair) compared to installation on the second portion **308***b* (i.e., the downhole portion).
(17) To receive the well properties from the sensor sub-assemblies, the controller **106** can be connected to the sensor sub-assemblies through wired connections, e.g., in series on in parallel. The wired connection that connects the controller **316** on the first portion **308***a* with the second sensor sub-assembly **310***b* on the second portion **308***b* can pass through or over the seal element **302**. Such a connection allows the second sensor sub-assembly **310***b* to transmit sensed well properties in the second portion **308***b* across the seal element **302** to the controller **316** in the first portion **308***a*. Alternatively or in addition, each sensor sub-assembly can include a transmitter that can wirelessly transmit the sensed well properties to a receiver included in the controller **316**.
(18) In some implementations, the controller **316** can include and/or operate as a transmitter that can transmit the well properties to a receiver **318** installed uphole of the controller **316**, e.g., at a surface **102** (FIG. **1**). The controller **316** and the receiver **318** can exchange signals, e.g., wirelessly or through wired connections. In some implementations, the receiver **318** can be a component of a controller similar to the controller **316**.

(19) As described above, the controller **316** can receive sensed well properties from well locations uphole and downhole of the seal element **302**. For example, the sensor sub-assemblies can be deployed in a tubing-casing annulus (TCA) defined by an outer surface of the liner **110** (FIG. **1**) and an inner surface of the casing **108** (FIG. **1**), but on either side of the seal element **302**. Each sensor sub-assembly can periodically (e.g., at a frequency of one or more times per second, one or more times per minute, one or more times per hour, in real-time) transmit sensed well properties to the controller **316**. In turn, the controller **316** can periodically transmit the received well properties to the receiver **318** at the surface **102** (FIG. **1**). Either during well construction or during well operation (or both), if the seal element **302** of the liner packer **204** maintains the fluidic isolation between the downhole portion and the uphole portion, the sensor sub-assemblies will not sense any appreciable change in the sensed well properties. However, if the fluidic isolation is not maintained, then the sensor sub-assemblies will sense a change in the sensed well properties. The controller **316** will receive the changed well properties and transmit the same to the receiver **318** at the surface **104**. An operator at the surface **104**, who receives the changed well properties, can implement corrective action. For example, a change in sensed pressure can indicate a leak that can necessitate well workover or other remedial operations or possibly well shutdown. In this manner, the well tool assembly **102** operates as a smart controller to monitor well properties and to allow a well operator to take corrective action in response to the well tool assembly **102** sensing a deviation in well properties from expected behavior.
(20) FIG. **4** is a flowchart of an example of a method **400** of implementing the well tool assembly of FIG. **1**. Some portions of the method **400** can be implemented by a well operator. Some portions of the method **400** can be implemented by a controller, e.g., the controller **316** (FIG. **3**). At **402**, a well tool assembly is formed. To do so, the seal element **302** (FIG. **3**) is attached to the outer surface **304** (FIG. **3**) of the liner packer **204** (FIG. **3**). The seal element **302** can fluidically seal the outer surface of the liner packer to an inner surface of the tubular (e.g., the casing **108** (FIG. **1**)) in which the liner packer is configured to be installed. The first sensor sub-assembly **310***a* is attached to the outer surface **304** of the liner packer on the first portion **308***a* of the liner packer between the seal element and the first end **306***a* of the liner packer. The second sensor sub-assembly **310***b* is attached to the outer surface **304** of the liner packer on the second portion **308***b* of the liner packer between the seal element and the second end **306***b* of the liner packer. The controller **316** is attached on the outer surface of the liner packer on the first portion. The liner hanger **202** (FIG. **2**) is coupled to the liner packer **204**.
(21) At **404**, the well tool assembly is run into the well **100** (FIG. **1**) and set at a downhole location in the well **100**. At **406**, well properties sensed by the first sensor and the second sensor are periodically received at a surface of the well. The well properties are received from the controller **316** at the receiver **318**. In some implementations, based on the well properties received at the surface, a change in the well properties is sensed by the second sensor sub-assembly or the first sensor sub-assembly. In response, corrective well operations can be performed.
(22) Implementations of the subject matter described here can diagnose and verify a correct seal across the liner packer. The well tool assembly described here can detect pressures above and below the liner packer. Diagnostic operations across the liner packer can be performed using the well properties sensed by the sensor sub-assemblies. Implementing the techniques described here can negate or reduce the need for complex rig intervention jobs. The sensor sub-assemblies can be deployed as permanent well installations to monitor variations between active formation environment and isolated well completion, which would allow well operators to determine possible communications across the packer elements during the well's lifetime.
(23) Thus, particular implementations of the subject matter have been described. Other implementations are within the scope of the following claims.

Claims

1. A well tool assembly comprising: a liner hanger configured to support a liner within a well, the liner hanger configured to be supported by a tubular installed within the well; and a liner packer coupled to the liner hanger, the liner packer configured to fluidically seal an outer surface of the liner hanger to an inner surface of the tubular, the liner packer comprising: a seal element on an outer surface of the liner packer, the seal element configured to fluidically seal the outer surface of the liner packer to the inner surface of the tubular, a first sensor sub-assembly attached to the outer surface of the liner packer on a first portion of the liner packer between the seal element and a first end of the liner packer, the first sensor sub-assembly configured to sense well properties in a first space between the outer surface of the liner packer and the inner surface of the tubular, a second sensor sub-assembly attached to the outer surface of the liner packer on a second portion of the liner packer between the seal element and a second end of the liner packer, the second end opposite the first end, the second sensor sub-assembly configured to sense well properties in a second space between the outer surface of the liner packer and the inner surface of the tubular, and a controller operatively coupled to the first sensor sub-assembly and the second sensor sub-assembly, the controller comprising one or more processors and a computer-readable medium storing instructions executable by the one or more processors to perform operations comprising: receiving sensed well properties from the first sensor sub-assembly and the second sensor sub-assembly, and transmitting the received sensed well properties to a receiver.
2. The assembly of claim 1, wherein, when the assembly is installed within the well, the first portion is uphole of the liner packer, and the second portion is downhole of the liner packer.
3. The assembly of claim 2, wherein the seal element is configured to fluidically isolate the first portion from the second portion.
4. The assembly of claim 2, wherein each of the first sensor sub-assembly and the second sensor sub-assembly, respectively, comprises: a pressure sensor configured to sense a pressure in the first portion and the second portion, respectively; and a temperature sensor configured to sense a temperature in the first portion and the second portion, respectively.
5. The assembly of claim 2, wherein the controller is attached to the first portion of the liner packer.
6. The assembly of claim 5, wherein the second sensor sub-assembly is configured to transmit the sensed well properties to the controller across the seal element.
7. The assembly of claim 1, further comprising the receiver configured to wirelessly receive the sensed well properties from the controller.
8. The assembly of claim 1, further comprising a liner tieback receptacle positioned between the liner hanger and the liner packer, the liner tieback receptacle configured to receive an end of the liner and to form a fluidically sealed conduit from the liner through the liner hanger.
9. A method comprising: forming a well tool assembly by: attaching a seal element to an outer surface of a liner packer, the seal element configured to fluidically seal the outer surface of the liner packer to an inner surface of a tubular in which the liner packer is configured to be installed, attaching a first sensor sub-assembly to the outer surface of the liner packer on a first portion of the liner packer between the seal element and a first end of the liner packer, attaching a second sensor sub-assembly to the outer surface of the liner packer on a second portion of the liner packer between the seal element and a second end of the liner packer, the second end opposite the first end, attaching a controller on the outer surface of the liner packer on the first portion, the controller configured to receive sensed well properties from the first sensor sub-assembly and the second sensor sub-assembly, and coupling a liner hanger to the liner packer, the liner hanger configured to support a liner within the well, the liner hanger supported by the tubular; running the well tool assembly into and setting the well tool assembly at a downhole location in a well; and periodically receiving, at a surface of the well and from the controller, the well properties sensed by the first

sensor sub-assembly and the second sensor sub-assembly.

10. The method of claim 9, wherein, after running the well tool assembly into and setting the well tool assembly at the downhole location in the well, the first portion is uphole of the liner packer, and the second portion is downhole of the liner packer, wherein the method comprises fluidically isolating the first portion from the second portion.

11. The method of claim 9, wherein each of the first sensor sub-assembly and the second sensor sub-assembly, respectively, comprises: a pressure sensor configured to sense a pressure in the first portion and the second portion, respectively, and a temperature sensor configured to sense a temperature in the first portion and the second portion, respectively, wherein the method further comprises: sensing, by each pressure sensor, the pressure in the first portion and the second portion, respectively; and sensing, by each temperature sensor, the temperature in the first portion and the second portion, respectively.

12. The method of claim 9, further comprising: determining, based on the well properties received at the surface, a change in the well properties sensed by the second sensor sub-assembly; and in response to the determining, performing corrective well operations.

13. The method of claim 12, wherein the change in the well properties comprises a change in the pressure sensed by a pressure sensor, wherein the pressure sensor is installed in an annulus between the outer surface of the liner packer and the inner surface of the tubular.

14. The method of claim 12, wherein the change in the well properties comprises a change in the temperature sensed by a temperature sensor, wherein the temperature sensor is installed in an annulus between the outer surface of the liner packer and the inner surface of the tubular.

15. The method of claim 12, wherein the corrective well operations comprise ceasing well operations until the corrective well operations have been completed.
