Land wellhead systems & offshore surface wellhead systems

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Objectives

- The objective of this chapter is to provide a brief overview of the types of wellhead systems and equipment commonly found on wells drilled in today’s oil and gas industry.

- First, we discuss two broad categories of **surface wellhead systems**:
  - onshore and
  - offshore.

- Then, we discuss wellhead systems used in subsea and ultra deepwater applications.
Outline

- Drilling a Well on Land
- Drilling a Well Offshore From a Jackup Drilling Rig Using Mudline Suspension Equipment
- The Unitized Wellhead
- Summary
Drilling a Well on Land

- When a well is drilled on land, an interface is required between the **individual casing strings** and the **blowout preventer (BOP) stack**.

This interface is required for four main reasons:

- To contain **pressure** through the **interface** with the **BOP stack**.
- To allow **casing strings** to be suspended so that no **weight is transferred to the drilling rig**.
- To allow **seals** to be made on the outside of each **casing string** to seal off the **individual annulus**.
- To provide **annulus access** to each **intermediate casing string** and the **production casing string**.
Drilling a Well on Land

Pressure Containment

- When drilling a well on land, a **spool wellhead system** is traditionally used.
- This wellhead is considered a "**build as you go**" wellhead system that is assembled as the **drilling process proceeds**.
Drilling a Well on Land

Pressure Containment

- The spool system consists of the following main components:
  
  - Starting casing head.
  - Intermediate casing spools.
  - Slip casing hanger and seal.
  - Tubing spool (if well is to be tested and/or completed).
  - Studs, nuts, ring gaskets, and associated accessories required to assemble the wellhead.
Drilling a Well on Land

Starting Casing Head

- The starting casing head attaches to the surface casing (conductor) by either welding or threading on to the conductor.

- The top of the starting casing head has a flange to mate with the bottom of the BOP.

- The flange must meet both size and pressure requirements.

- The starting casing head has a profile located in the inside diameter (ID) that will accept a slip-and-seal assembly to land and support the next string of casing.
Drilling a Well on Land

Starting Casing Head

- The **slip-and-seal assembly** transfers all of the **casing weight** to the conductor while **energizing a weight-set elastomeric seal**.

Photo of a starting casing head and installation components. This casing head is typical of a thread-on or weld-on configuration used in land drilling operations.
Drilling a Well on Land

Starting Casing Head

Photo of a starting casing head and slip-and-seal assembly with installation components. This casing head has a gusseted base plate typically seen in jackup drilling operations.
Drilling a Well on Land

Intermediate Casing Spools

- The intermediate casing spool is typically a flanged-by-flanged pressure vessel with outlets for annulus access.

- The intermediate casing spool (or spools) is installed after each additional casing string has been run, cemented, and set.

- The bottom section of each intermediate casing spool seals on the outside diameter (OD) of the last casing string that was installed.

- The bottom flange will mate with the starting casing head or the previous intermediate casing spool.
Drilling a Well on Land

Intermediate Casing Spools

- The top flange will have a **pressure rating higher** than the **bottom flange** to cope with expected **higher wellbore pressures** as that hole section is drilled deeper.

Photo of a typical intermediate casing head and additional components required to assemble it during the drilling operation.
Drilling a Well on Land

Intermediate Casing Spools

- The **intermediate casing spool** also incorporates a **profile located in the ID**, which accepts a **slip-and-seal assembly** similar to the one installed in the starting **casing head**.

- This **slip** and **seal** will be sized in accordance with the casing program.
Drilling a Well on Land

Tubing Spool

- The tubing spool, is the last spool installed before the well is completed.

- The tubing spool differs from the intermediate spool in one way: it has a profile for accepting a solid body-tubing hanger with a lockdown feature located around the top flange.

Photo of a typical tubing head with installation components.
Drilling a Well on Land

Tubing Spool

- The **lockdown** feature ensures that the **tubing hanger** cannot move because of **pressure or temperature**.

- The **flange sizes** vary in accordance with **pressure requirements**.
Drilling a Well on Land

Load-Carrying Components

- Casing weight is transferred to the **starting casing head** and **intermediate spools** with two different types of hanger systems:
  - A slip-and-seal casing-hanger assembly.
  - A mandrel-style casing hanger.

Photo of a typical weight-set slip-and-seal assembly with casing-head installation components.
Drilling a Well on Land

Load-Carrying Components

- The slip-and-seal casing-hanger assembly has an OD profile that mates with the internal profile of the starting casing head and intermediate casing spools.

- Integral to this casing-hanger assembly is a set of slips with a tapered wedge-type back and serrated teeth that bite into the OD of the casing being suspended.

- When the casing has been run and cemented, the BOP is disconnected from the casing spool and lifted up to gain access to the spool bowl area.
Drilling a Well on Land

Load-Carrying Components

- After the **slip-and-seal casing-hanger assembly** is installed, the travelling block will lower the casing and set a predetermined amount of **casing load** onto the **slip-and-seal casing-hanger assembly**.

- The teeth on the slips will engage the pipe OD and transfer the suspended weight of the casing to the starting casing head.

- As the slips travel down, they are forced in against the casing, applying greater and greater support capacity.
Drilling a Well on Land

Load-Carrying Components

- As the **slips continue to engage the pipe**, a load is placed on the **automatic weight-set elastomeric seal assembly**, sealing the annulus between the casing and the casing head.

- This **installation creates a pressure barrier** and isolates the annular pressure below the **slip-and-seal casing hanger** from the wellbore.

- Traditionally, **mandrel hangers** are used only to suspend tubing from the **tubing head**.
Drilling a Well on Land

Load-Carrying Components

Illustration (cutaway) of a mandrel-type tubing hanger.

- Occasionally, they can also be used in intermediate casing spools as an alternative to the slip-and-seal casing-hanger assembly.

- The mandrel hanger is a solid body with a through-bore ID similar to that of the tubing or casing run below, and it also has penetrations for downhole safety valve line(s) and temperature and pressure gauges, if required.
Drilling a Well on Land

Load-Carrying Components

- Traditionally in spool wellheads, elastomeric seals are used to seal the annulus between the casing-spool body and the casing or tubing hanger.
Drilling a Well on Land

Annulus Seals

- The seals used on spool wellhead systems are traditionally elastomeric.

- This is primarily because the seal must be energized against the casing-bowl ID and must also seal against the rough finish of the casing OD.

- This elastomeric sealing system is used for the slip-and-seal assembly as well as the bottom of the intermediate casing or tubing spools.
Drilling a Well on Land

Annulus Seals

- The slip-and-seal assembly provides a primary annulus seal, while the elastomeric seal in the bottom of each casing and tubing spool also provides a seal.

- The casing-spool flange connection becomes a secondary seal for both annulus and wellbore pressure.

- The elastomeric seals are manufactured using different materials to allow for various pressures, produced fluids, and other environmental conditions.
Drilling a Well on Land

Annulus Seals

- The exception is the seal between each flange face, which is a metal-to-metal sealing ring gasket that provides a pressure-tight seal between each of the spool flanges.

- Ring gaskets are also used between the wellhead and the BOP stack, as well as the valves used for annulus access.

- While drilling the well, it is required that the seal bores in each of the intermediate casing spools and tubing spools be protected.
Drilling a Well on Land

Annulus Seals

A series of wear bushings are supplied to protect the seal areas discussed during the drilling operation.

Photos of the wear bushings for a typical land drilling wellhead system.
Drilling a Well on Land

Annulus Seals

- The wear bushings are run on a drillpipe tool with J-lugs located on the OD that interface with J-slots located in the top ID section of the wear bushing.

- It is also required that the flanged connections between each spool and the BOP be tested during the drilling and completion phases.

Photo of the wear bushing running tools. These tools are also used to test the BOP stack.
Drilling a Well on Land

Annulus Seals

- The tools required are available from the equipment supplier.

- The tool used for testing the BOP is typically a **plug type** with a **heavy-duty elastomer seal**.

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Drilling a Well on Land

Annulus Access

- For onshore wells, during the **drilling operation**, access to **each annulus** is required for the following reasons:
  - To provide a **flow-by area** for returns during **cementing of casing strings**.
  - To provide access for possible **well kill operations**.
  - To monitor the **annulus** for **pressure below the slip-and-seal assembly**.
Drilling a Well on Land

Product Material Specifications

- When ordering wellhead equipment, the following should be considered:
  - All surface wellhead equipment and gate valves should be manufactured to the latest edition of the American Petroleum Inst. (API) and Intl. Organization for Standardization (ISO) standards.

- These standards define equipment specifications as follows:
  - Material class: based on produced fluids; AA, BB, CC, DD, EE, FF, and HH
  - Temperature range: 75 to +350°F.
Drilling a Well Offshore From a Jackup Drilling Rig Using Mudline Suspension Equipment
Drilling a Well on Jackup Rig

Mudline Suspension System

- From a **historic point of view**, as jackup drilling vessels drilled in deeper water, the need to transfer the weight of the well to the seabed and provide a disconnect-and-reconnect capability became clearly beneficial.

- This series of **hangers**, called **mudline suspension equipment**, provides **landing rings** and **shoulders** to transfer the weight of **each casing string** to **the conductor and the sea bed**.
Drilling a Well on Jackup Rig

Mudline Suspension System

- The mudline hanger system consists of the following components:
  - Butt-weld sub.
  - Shoulder hangers.
  - Split-ring hangers.
  - Mudline hanger running tools.
  - Temporary abandonment caps and running tool.
  - Tieback tools.
  - Cleanout tools.
Drilling a Well on Jackup Rig

Mudline Hangers

- Each mudline hanger landing shoulder and landing ring centralizes the hanger body and establishes concentricity around the center line of the well.

- Concentricity is important when tying the well back to the surface.

- In addition, each hanger body stacks down relative to the previously installed hanger for washout efficiency.

- Washout efficiency is necessary to clean the annulus area of the previously run mudline hanger and running tool.
Drilling a Well on Jackup Rig

Mudline Hangers

- This ensures that cement and debris cannot hinder disconnect and retrieval of each casing riser to the rig floor upon abandonment of the well.

All mudline hangers should stack down to provide washout efficiency. Washout efficiency is supplied by a series of wash ports located in the running tool that (when opened for washing out) are positioned below the running tool attached to the previously run mudline hanger.
Drilling a Well on Jackup Rig

Mudline Hangers

- The main difference between the wellheads used in the land drilling application and the jackup drilling application (with mudline) is the slip-and-seal assembly.

- Because the weight of the well now sits at the seabed, a weight-set slip-and-seal assembly is not used.
Drilling a Well on Jackup Rig

Mudline Hangers

Instead, a **mechanical set (energizing the seal by hand)** is used, in which **cap screws** are made up with a **wrench** against an **upper compression plate** on the **slip-and-seal assembly** to energize the **elastomeric seal.**
Drilling a Well on Jackup Rig

Temporarily Abandoning the Well

- The mudline suspension system also allows the well to be temporarily abandoned (disconnected) when "TD" is achieved (when drilling is finished at total depth).

- When this occurs, the conductor is normally cut approximately 5 to 6 ft above the mudline and retrieved to the surface.
Drilling a Well on Jackup Rig

Temporarily Abandoning the Well

- After each casing string is disconnected from the mudline suspension hanger and retrieved to the rig floor in the reverse order of the drilling process, threaded temporary abandonment caps or stab-in temporary abandonment caps (both of which makeup into the threaded running profile of the mudline hanger) are installed in selected mudline hanger before the drilling vessel finishes and leaves the location.
Drilling a Well on Jackup Rig

Temporarily Abandoning the Well

- The **temporary abandonment caps** can be retrieved with the same tool that installed them.
Drilling a Well on Jackup Rig

Reconnecting to the Well

- A **mudline suspension system** also incorporates **tieback tools** to reconnect the **mudline hanger** to the surface for **re-entry and / or completion**.

These tieback tools can be of two types:

- threaded and
- stab-in

- The **tieback** tools are different from the **running tools** in that they makeup into their own dedicated right-hand makeup threaded profile.
Drilling a Well on Jackup Rig

Reconnecting to the Well

- The **stab-in tieback tool** offers a **simple, weight-set, rotation-lock design** that provides an easy way to tie the **well back to the surface**.

- A **surface wellhead system** is installed, and the well is completed similarly to the method used on land drilling operations.

- The **mudline suspension system** has been designed to accommodate tying the **well back** to the surface for surface completion, and it also can be adapted for a **subsea production tree**.
Drilling a Well on Jackup Rig

Reconnecting to the Well

- A tieback tubing head can be installed to the mudline suspension system at the seabed, and a subsea tree can be installed on this tubing head.
The Unitized Wellhead

- The **unitized wellhead** is very different from the **spool wellhead system** because it incorporates different design characteristics and features.

- The **unitized wellhead**, is a one-piece body that is typically run on 13 3/8-in. casing through the **BOP** and **lands** on a **landing shoulder** located inside the **starting head** or on **top of the conductor itself**.

- The **casing hangers** used are **threaded** and **preassembled** with a pup joint.

- This way, the **threaded connection** can be pressure tested before leaving the factory, ensuring that the assembly will have **pressure-containing competence**.
The Unitized Wellhead

- **Gate valves** are installed on the external outlet connections of the **unitized wellhead** to enable annulus access to each of the **intermediate** and the **production casing strings**.

Illustration of a typical unitized wellhead system for land applications. Offshore unitized wellhead systems are typically similar but include the use of a metal-to-metal seal assembly.
The Unitized Wellhead

- After the **next hole section** is drilled, the **casing string**, topped out with its **mandrel hanger**, is run and landed on a shoulder located in the ID of the **unitized wellhead**.

- A **seal assembly** is run on a **drillpipe tool** to complete the **casing-hanger** and **seal-installation process**.

- Each **additional intermediate casing string** and **mandrel hanger** is run and landed on top of the previously **installed casing hanger** without removing the BOP stack.
The Unitized Wellhead

- Besides saving **valuable rig time**, the other advantage of the unitized wellhead system over spool wellhead systems is **complete BOP control** throughout the entire **drilling process**.

Photo of a 13¾-in. 5,000-psi unitized wellhead system and its major components.
The Unitized Wellhead

The unitized wellhead consists of the following components:

- Unitized wellhead body.
- Annulus gate valves.
- Mandrel casing hangers.
- Mandrel tubing hangers.
- Metal-to-metal sealing for the annulus seals.
The Unitized Wellhead

Mandrel Casing Hangers

- The mandrel casing hangers are a one-piece construction and are manufactured to meet the casing and thread types specified by the customer.

- The mandrel casing hanger has a 4° tapered sealing area on its OD. The mandrel hanger still also incorporates running threads and seal-assembly threads to facilitate installation.

- The hanger carries a lock ring that locks the hanger down when the seal assembly is installed.
The Unitized Wellhead

Mandrel Casing Hangers

- The **mandrel casing hanger** lands on either the **shoulder** located in the bottom of the **unitized wellhead body** or on top of the previous **casing hanger**.
The Unitized Wellhead

Seal Assembly

- The seal assembly incorporates a metal-to-metal or elastomeric seal which is run on a running tool through the BOP stack once the casing has been cemented.

- The seal assembly seals off the pressure from above and below and isolates the annulus from the wellbore.
The Unitized Wellhead

Seal Assembly

- The **annulus** can still be monitored through the outlets on the **unitized wellhead body** and the **gate valves** mounted to them.

Photo of a seal assembly for the mandrel hanger. This seal assembly features elastomeric seals, but it also can feature true metal-to-metal seals.
The Unitized Wellhead

There is a full range of tools available for the unitized wellhead system:

- Wellhead-housing running tool.
- BOP test tool.
- Casing-hanger running tool.
- Seal-assembly running and retrieving tool.
- Wear-bushing running and retrieving tool.

Note:

The unitized wellhead is more often used with platform-development projects than with exploration applications.
Summary

- As has been discussed in this series, wellhead systems (whether the application is surface wellheads on land, jackup or offshore production platforms, or subsea wellheads) serve as the termination point of casing and tubing strings.

- As such, these systems control pressure and provide access to the main bore of the casing or tubing or to the annulus.

- This pressure-controlled access allows drilling and completion activities to take place safely and with minimal environmental risk.

- Multiple barriers are used, such as primary and secondary seals, to reduce risk in case of equipment failure.
Summary

- **Offshore wellhead systems** are normally more sophisticated in design to handle **ocean currents**, **bending loads**, and **other loads** induced by the environment during the life of the well.

- Some of these loads are **cyclic in nature**, so **fatigue-resistant designs** are desirable, particularly for deepwater developments.

- Material specifications play an important role in equipment performance; organizations such as API, the American Soc. of Mechanical Engineers (ASME), and NACE Intl. offer helpful standards to provide cost-effective solutions to technical challenges.
References


References


References


References


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