Land wellhead systems & offshore surface wellhead systems

Presented by

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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.

Photo of the wear bushing running tools. These tools are also used to test the BOP stack.

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

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**.

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.

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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

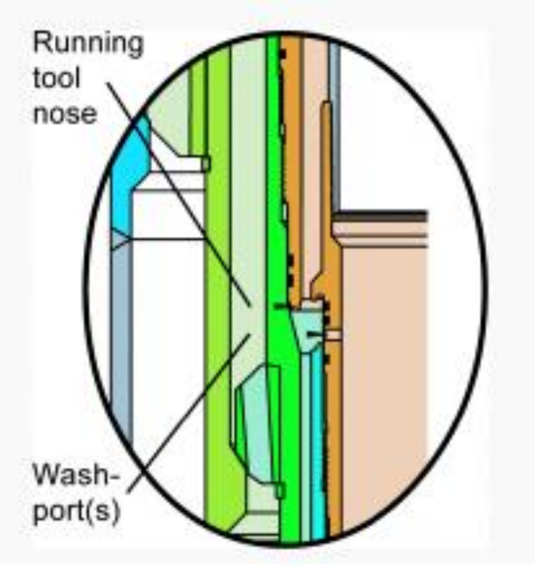
- Each **mudline hanger landing shoulder** and landing ring centralizes the hanger body and establishes concentricity around the center line of the well.
- Concentricity is important when tying the well back to the surface.
- In addition, each **hanger body stacks down** relative to the previously **installed 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.

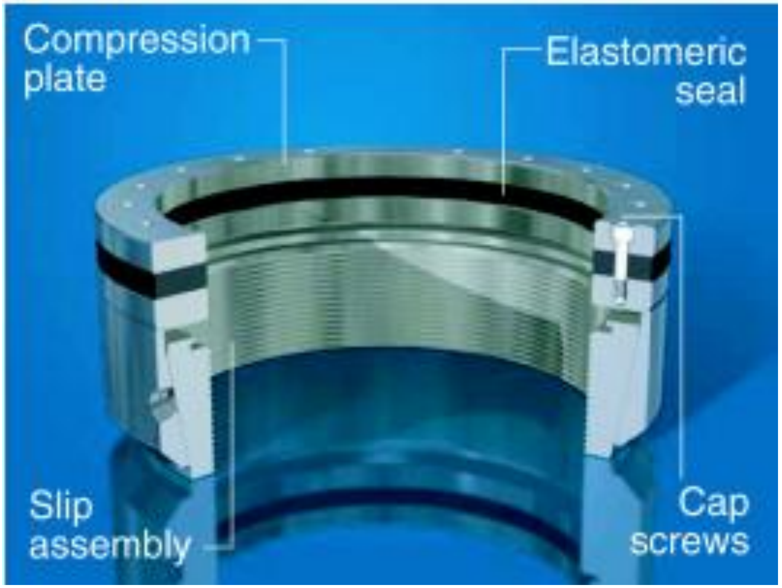


Drilling a Well on Jackup Rig

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**.

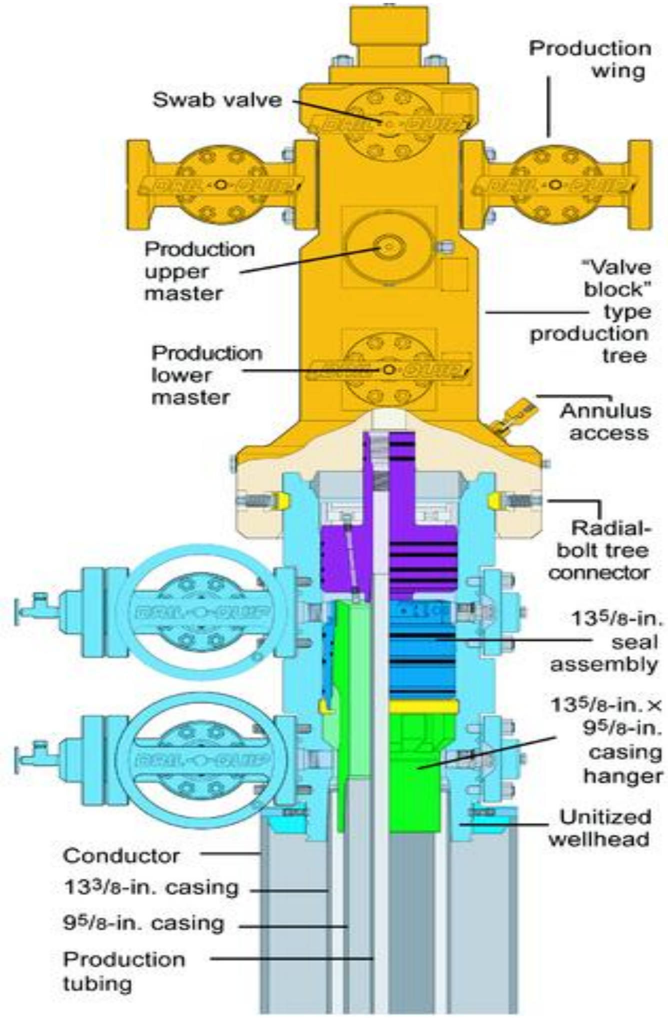


Illustration of a typical unitized wellhead system for land applications. Offshore unitized wellhead systems are typically similar but include the use of a metal-to-metal seal assembly.

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 13⅝-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**.

Photo of a unitized wellhead mandrel 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.

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