Introduction to Directional Drilling

Directional drilling is defined as the practice of controlling the direction and deviation of a well bore to a predetermined underground target or location.

Module Objectives

Describe the purposes of directional drilling.

Describe typical directional drilling applications.

Differentiate among the basic hole types.

Summarize the duties of the directional driller.

Summarize data that must be obtained during prejob meeting with customer.

Purposes of Directional Drilling

Purposes of directional drilling include:

- To obtain production from inaccessible locations, such as under populated areas, river beds, plants, and roads.
- To sidetrack a vertical well bore, either up-dip or down-dip, to seek the oil bearing formations after the original well drilled into water or gas.
- To reduce the cost of offshore drilling and production by drilling a large number of directional wells from one platform or island.
- To provide fault control
- To drill a relief well to kill a well blowing out of control.

Obtaining Production from Inaccessible Locations

Inaccessible locations of producing formation dictates remote rig location and directional drilling. Producing zones on land may be located under cities, surface installations, etc. These zones may also be under river beds, mountains, harbors, roads, etc. When difficulty is found in obtaining rig locations, multiple wells are drilled from one location in a manner similar to that used in offshore locations.

Sidetracking into Multiple Sands from a Single Well Bore

A very profitable application of directional drilling pertains to the intersection of multiple sands from a single well bore. There are certain cases where the attitudes of the producing formations are such that the most economical approach is a directional
well for a multiple completion. This method would be applicable to multiple sands underneath a salt dome overhang, sands underneath an unconformity, and sands adjacent to a fault plane.

**Drilling Multiple Wells from a Single Location**

Directional drilling has helped to greatly cut the platform and production costs through the drilling of a number of wells from one location. Without the use of controlled directional drilling, it would have been impossible to develop offshore oil deposits economically.

**Controlling Faults**

In fault control, the well bore may be deflected across or parallel to the fault for better production. It is sometimes difficult to drill a vertical well through a steeply inclined fault plane to reach an underlying oil sand. A well situated on the footwall side of the fault plane may be deflected to penetrate the oil-bearing strata. The well might be drilled on the hanging wall side of the fault plane and, at an appropriate depth, deflected to penetrate the fault plane at approximately right angles.

**Drilling Relief Wells**

The most spectacular application of directional drilling has been its use in connection with the drilling of a relief well to intersect a blown out well near its bottom so that kill fluid may be pumped down into the hole to kill the well. Basic and fundamental techniques are the same as those utilized in conventional controlled directional drilling. The targeted bottom hole location may require extreme accuracy.

**Directional Drilling Applications**

Applications of directional drilling include:

- Extended-reach drilling
- Horizontal drilling
- Multilateral drilling
- Underbalanced horizontal drilling
- Steam-Assisted Gravity Drainage (SAGD)
- Reentry drilling
- Coiled tubing applications
- Short radius drilling
Extended-Reach Drilling

Sperry-Sun’s engineered drilling solutions have been instrumental in helping operators set new records for horizontal displacement, both economically and efficiently. Extended-reach wells that extend for miles before reaching the reservoir target add value to drilling operations by making it possible to:

- Replace subsea wells and tap offshore reservoirs from fewer platforms,
- Develop near shore fields from onshore, and
- Reduce environmental impact by developing fields from pads.

![Figure 1 Extended-reach drilling](image)

Customized Bottom Hole Assemblies

Sperry-Sun also provides customized BHAs which limit hole tortuosity and allow maximum steering capability, while maintaining hole inclination.

Efficient hole cleaning and cuttings removal is a crucial factor in successful extended-reach drilling. To deliver the high drillstring rotational speeds necessary to clean the highly deviated sections of extended-reach wells, Sperry-Sun has developed specially designed Sperry Drill motors to allow for drillstring rotation up to 200 rpm.

In addition, Sperry-Sun can drill farther and faster with our Adjustable Gauge Stabilizers (AGS). The AGS allows inclination control while drilling in rotary mode.
Horizontal Drilling

To meet the price-cost challenges of today’s oil and gas market, operators commonly turn to horizontal drilling to improve production and return on investment from both new and reentry wells. Sperry-Sun is a leading force in the advancement of horizontal drilling technology. In the North Sea, we were the first to drill horizontal wells in the norther UK, Norwegian, and Danish sectors. We have drilled the majority of horizontal wells in Canada. In locations as diverse as Western Siberia, the Middle East, Indonesia, and South Texas, Sperry-Sun assists customers achieve even their most ambitious drilling plans.

Guiding a drillstring along a horizontal path and keeping it within a narrow pay zone requires reliable hardware, advanced navigation systems, expert directional drilling, and careful well planning. Sperry-Sun’s complete horizontal drilling systems include:

- Steerable motors
- Instrumented motors for geosteering applications
- Drilling tools
- Surveying/orientation services
- Surface logging systems
- At-bit inclination

Using these systems, our horizontal drilling teams can continuously measure and evaluate drilling parameters in real-time, monitor and control well path trajectory, and provide formation evaluation information while drilling. Our geosteering capabilities are used to locate reservoirs, identify gas/oil contacts, effectively place and keep horizontal wellbores within a formation boundary, and interactively steer to and through the optimum sections of a reservoir. The result is the optimum use of drilling investment through wells that are drilled and evaluated in the most efficient manner possible.
Figure 2  Horizontal drilling
Multilateral Drilling

Sperry-Sun’s proven expertise meets the challenge of producing more oil and gas, while reducing the customer’s cost base. Multilateral horizontal wells - wells with multiple laterals drilled from a single main wellbore - offer a cost effective way to improve reservoir drainage and return on investment.

Multilaterals, which can be used for both new and reentry wells, offer the ability to drain a single reservoir (or multiple reservoirs) with high efficiency. In addition, using multiple laterals can reduce the number of surface locations, which, in turn, lessens environmental impact and reduces overall project cost.

The use of multiple laterals in a single reservoir greatly increases the total formation exposure and allows drainage over a greater area. In fractured reservoirs, additional laterals increase the probability of intercepting and draining different fracture systems. The efficiency of enhanced oil recovery schemes can also be increased through the use of multilateral wells.

Figure 3  Multilateral drilling
Sperry-Sun recognizes the importance of wellbore integrity and re-access to secondary laterals. Sperry-Sun leads the industry in multilateral drilling and completion systems that allow operators to gain greater reservoir exposure and significantly reduce overall drilling and exploitation costs for entire fields by drilling and casing multiple lateral wellbores from a single primary wellbore.

**The Lateral Tie-Back System (LTBS™)**

The Lateral Tie-Back System (LTBS™) allows all laterals to be cased and provides a complex interconnection of individual production liners with total wellbore integrity. This system does not require cement operations to line the lateral. Multiple laterals may be drilled at virtually any predetermined depth in a new vertical, directional, or horizontal wellbore, and also at any time during the productive life cycle of the well. This system allows for quick reentry into all laterals for well servicing and workovers. This system mechanically ties back the secondary laterals to the main wellbore.

**The Retrievable Multilateral System (RMLS™)**

The Retrievable Multilateral System (RMLS™) offers great flexibility in the casing of secondary laterals. This system utilizes cement to assist in tieing back to the main wellbore. Wellbore integrity is kept intact by the cement at the juncture between the main wellbore and the secondary laterals.

**The Reentry Drilling System (RDS™)**

The Reentry Drilling System (RDS™) uses a proprietary oriented milling technology to allow multilaterals to be drilled and completed at any time in a cased wellbore. The RDS is comprised of a latch system, a hydraulic set packer, a retrievable deflection tool, and a milling assembly. The RDS can be set to a specific orientation and depth after which the assembly is locked in place by the hydraulic packer. A window is then milled through the casing, and a lateral can be drilled and cased. The RDS uses the same proprietary oriented latch system as the LTBS and RMLS.

**Lateral Reentry System (LRS™)**

In conjunction with Dresser Oil Tools and other parties, completion systems have been developed specifically for Sperry-Sun’s multilateral systems and provide a variety of options for the production requirements of the well. Dresser Oil Tools’ Lateral Reentry System (LRS™) provides both lateral isolation, as well as lateral reentry capabilities for logging, perforating, or other workover activities in a monobore completion.

**Multi-String Completion System (MSCS™)**

The Multi-String Completion System (MSCS™) is a dual completion system specifically designed for Sperry-Sun’s multilateral systems. The MSCS offers separate flow, treating, and workover capabilities for segregated production with through-tubing intervention and lateral reentry capabilities.
Underbalanced Horizontal Drilling

Underbalanced horizontal drilling uses gasified drilling fluids to keep the hydrostatic head lower than the pressure of the formation being drilled. This offers a safe and economical means of improving production rates and increases the percentage of hydrocarbons ultimately recovered, particularly from older, low pressure reservoirs. This method can achieve production rates of three (3) to ten (10) times that of similar, overbalanced horizontal wells, along with average increases in rate of penetration of up to four times.

Figure 4 Underbalanced horizontal drilling
Drilling underbalanced:

- Minimizes skin damage,
- Reduces lost circulation and stuck pipe incidents,
- Increases ROP while extending bit life, and
- Reduces or eliminates the need for costly stimulation programs.

Sperry-Sun has drilled hundreds of horizontal underbalanced wells using through-drillstring injection, parasite string injection, and microannulus injection methods.

Sperry-Sun’s comprehensive systems and services for underbalanced horizontal drilling incorporate proven tools and technology, augmented by technology specifically designed to facilitate this process. These technologies include:

- Sperry Drill air motors
- Pressure While Drilling (PWD) sensors that help optimize gas injection rates
- Electromagnetic MWD (EMMWD) sensors to transmit data in air or gasified drilling fluids
- Downhole BHA orienter for coiled tubing drilling
- SENTRY monitoring software which integrates flowline pressure, pit and separator volumes, flowline H₂S sensors, and gas injection rates in one display to give a complete picture of the circulating system
- Hydrostatic Control Valve (HCV) to prevent fluid flow either out of or into the drillstring during connections and to prevent kicks from entering the drillstring during connections.
Steam-Assisted Gravity Drainage (SAGD)

In the past, methods for producing heavy oil were expensive and ineffective at best. With the advent of horizontal wells, and later multilateral wells, heavy oil production efficiency increased. However, these recovery methods still left most the reserves in the ground.

With the introduction of Steam-Assisted Gravity Drainage (SAGD), production efficiencies of up to 60 percent or better are now possible in heavy oil reserves. Originally developed by the Alberta, Canada, Department of Energy (formerly AOSTRA), the SAGD technique utilizes two horizontal wells, one drilled above the other, and steam injection to enhance the recovery of heavy oil. Steam is injected into the upper well, and the heated heavy oil and condensed steam are produced from the lower well. Reduced oil viscosity, along with the improved sweep and displacement efficiency, provides a higher percentage of recovery than traditional enhanced oil recovery methods.

![Figure 5 Magnetic Guidance Tool used for drilling a Steam-Assisted Gravity Drainage Well](image)
The SAGD method requires consistent separation and alignment between both horizontal wells. The separation distance of the twin wells can vary greatly, depending on reservoir characteristics, and separation of between 4 and 20 meters is typical. SAGD’s success depends entirely on maintaining exact separation and alignment over the entire injection/production interval. If the wells are drilled too close together, the steam injected in the upper well can break through, or directly communicate, to the lower well. Drilling the wells too far apart results in no production because the steam injection cannot heat the volume between the wells enough to allow gravity drainage to occur.

No conventional survey method can perform within the tight tolerances required by SAGD over long intervals. To achieve the accuracy required for drilling SAGD wells, Sperry-Sun co-developed the Magnetic Guidance Tool (MGT) with Vector Magnetics, Inc. The MGT, its associated software, and specially modified Sperry-Sun MWD sensors make it possible to drill parallel wells in proximity to one another with much greater accuracy than using conventional borehole surveying instruments.

The MGT is a downhole, electromagnetic source used with a modified MWD directional sensor to measure the vertical and horizontal separation of two wells. The MGT/MWD technique can be thought of as using a measuring tape to measure the distance and direction between the center of the MGT and the MWD sensors. The strength and direction of the electromagnetic field generated by the MGT is measured by the MWD probe, providing a beacon in the lower well to guide drilling of the upper well at a specified separation.

The lower well is drilled using conventional directional control procedures, and the upper well is drilled using the MGT/MWD method. By placing the MGT in the lower well and Sperry-Sun’s modified MWD sensors in the upper well, the known strength and orientation of the MGT is used to compute distance and alignment between the two wells.

After both wells have been drilled, the upper well is then used for steam injection and the lower well produces the heated oil and condensed steam, which are separated at the surface.
Reentry Drilling

For re-developing older reservoirs and increasing recoverable oil in place, horizontal reentries add value to drilling operations by using the existing well structure to increase production or tap into new zones. Reentry drilling provides operators with the ability to effectively exploit all the oil and gas in their reserves.

Sperry-Sun has developed numerous technologies designed specifically for reentry applications. These include:

- Short radius drilling systems which can drill a lateral from vertical to horizontal within 60 ft TVD of kickoff
- Slimhole drilling systems that are accurate, economical, and have less environmental impact than full-sized systems
• Coiled tubing drilling systems, which reduce the overall cost of drilling horizontal or directional wells
• the Reentry Drilling System (RDS), which provides multilateral capabilities at any time during the life cycle of the wellbore

**Coiled Tubing Applications**

Sperry-Sun has utilized coiled tubing in several different drilling applications, including horizontal, underbalanced, and reentry drilling. This system offers several advantages over traditional drilling systems. Coiled tubing drilling can reduce the overall cost of drilling horizontal or directional wells. The coiled tubing apparatus allows the drillstring to trip in and out of the well faster than conventional drillstrings. It also reduces the environmental impact of drilling operations.

![Coiled tubing applications](image-url)

**Figure 7  Coiled tubing applications**
Sperry-Sun offers all engineering and downhole elements operators need for coiled tubing operation:

- project engineering
- detailed well planning
- expert directional supervision
- customized BHA's
- specialized orienters

Sperry-Sun's customized BHA's and orienters ensure that the coiled tubing operation runs smoothly and efficiently. Our new coiled tubing orienter, combined with Sperry-Sun's proven MWD and Sperry Drill motor, provides a complete downhole system for drilling directional and horizontal wells. This new orienter derives its indexing force from the pressure force across the BHA and is actuated by the pumps-on/pumps-off action of the rig pumps.

The 3 inch orienter is used in holes from 3-3/4” to 3-7/8” in diameter. the 3-5/8” orienter is used in holes form 4-1/8” to 4-3/4” in diameter.

**Short Radius Drilling**

Sperry-Sun’s short radius drilling system provides precise directional control. Whether re-entering a well where it is advantageous to have a cased wellbore above or in the target formation, or whether it is advantageous to set casing above the target reservoir, this system will perform to the operator’s specifications.

Sperry-Sun’s system is most effective for 90 to 105 degree dogleg rates. This equates to a 63-3/5 ft to 54-1/2 ft radius curve. Our 4-3/4” tools can be used to drill 5-7/8” to 6-1/8” hole sizes. Our system had drilled vertical sections in excess of 650 feet, with longer sections possible.

Short radius drilling allows the casing to be set above or in the target reservoir. This results in:

- minimization of vertical formation exposure in which long radius curves are encountered
- isolation of unstable formations
- isolation of gas caps, by drilling a lateral section through the fluid producing zone

Short radius drilling allows operators to intersect missed targets, such as fractures, pinnacle reefs, or pockets of porosity. It can also be utilized for:

- depleted or low pressure reservoirs where formation pressures are insufficient to lift fluid above a longer radius curve
- wells where boundaries or well spacing constraints do not allow long vertical sections of a long or medium radius well
Sperry-Sun’s short radius drilling system provides precise directional control of azimuth and hole inclination. The system consists of Sperry Drill articulated build and lateral motors, an articulated MWD tool, and an electronic multishot assembly.

The build motor features a reduced length power section, which minimizes the distance between the bit and the MWD tool. Two power sections are joined by an articulated coupling to ensure ease of sliding through the build section. The lateral motor can be equipped with a third power section for increased penetration rates. The motor is designed for drilling in both oriented and rotary modes.

Sperry-Sun’s articulated MWD is specially designed to traverse short radius build sections without incurring high bending stresses. The high strength, nonmagnetic collars can traverse 100°/100 ft (30 m) doglegs sliding and can be rotated in the lateral section.

The articulated multishot assembly allows the Electronic Survey System (ESS) to be used for an accurate survey of the short radius well after drilling and before the casing is set. The nonmagnetic multishot assembly allows surveys to be run within 3 ft (1 m) of the end of the wellbore. The electronic multishot can store up to 3,000 surveys.
Basic Hole Types

In a preplanned, deflected bore hole, a carefully conceived and executed drilling program, based on geological information, knowledge of the selection of the correct tools, mud, and casing programs, and target point may ensure optimum success of the well program. Actual experience over recent years has patterned traditional directional drilling to three basic types.

Type I Holes

A Type 1 hole is planned so that the initial deflection angle is obtained at a shallow depth and from that point on the angle is maintained as a straight line to the target zone. Once the angle and deflection are obtained, casing may be set through the deviated section and cemented.

Generally, Type I holes can be employed in two distinct depth programs. It can be used for moderate depth drilling in areas where intermediate casing is not required and where oil-bearing strata is a single horizon. It can also be used for deeper wells requiring a large lateral displacement. In this case, an intermediate casing string can be set to the required depth, and then the angle and direction can be maintained after drilling out below this string.

Figure 9  Example of a Type I Hole.
**Type II Holes**

A Type II hole (S well) also sets the initial deflection angle near the surface. After the angle is set, drilling continues on this line until the appropriate lateral displacement is attained. The hole is then returned to vertical, or near vertical, and drilled until objective depth is reached. Surface casing is set through the upper deviated section and cemented. The well bore is then continued at desired angle until the lateral displacement has been reached and the well bore returned to vertical. Intermediate casing is set through the lower vertical return section. Drilling is then continued below the intermediate casing in a vertical hole. This type is employed on deep wells in areas where gas troubles, salt water flows, etc., dictate the setting of intermediate casing. It permits more accurate bottom hole spacing in a multiple pay area. Deflection angle may be set in surface zones where drilling is fast and round trip costs can be held to a minimum. When the hole has been returned to vertical and the intermediate casing has been set, the directional drilling engineer can be released.

![Figure 10: Example of a Type II Hole.](image)
Type III Holes

A Type III hole starts its deviation well below the surface. The angle is usually a constant build to the target point. Deflection angles may be relatively high and lateral distances from vertical to desired penetration point relatively shorter than the other types. Typical applications would be exploring a stratigraphic trap or obtaining additional geological data on a non-commercial well. Since deflection operations take place deep in the hole, trip time for such operations is high and the deflected part of the hole is not normally protected by casing.

Figure 11  Example of a Type III Hole.
Responsibilities at the Rigsite

The directional driller has the following responsibilities at the rigsite:

1. Check the accuracy of all plots, printouts, and other relevant well information.
2. Maintain an up-to-date record of all directional drilling parameters and detailed description of the assembly used to drill each hole section.
3. Advise the drilling supervisor/coordinator on BHA selection, directional drilling tool performance, well-to-well clearances, ellipse of uncertainty, and survey calculations.
4. Perform all normal rigsite calculations associated with directional drilling. This will include all survey calculations, well-to-well clearance calculations, ellipse of uncertainty calculations, and well path projections.
5. Prepare a daily directional drilling report, BHA report, survey calculation report, and drilling parameters report to be copied to the drilling supervisor.
6. Ensure that the directional drilling aspects of the well being drilled comply with the approved drilling program. If a deviation from the well plan is required, then authorization for such deviation will be sought from the drilling supervisor/coordinator.
7. Inspect all directional drilling tools when delivered to the rigsite, ensuring that the correct numbers, configurations, parts, spares, and documentation are present to carry out the work. The directional driller will gauge and measure all directional assemblies prior to and after being retrieved from the wellbore.
8. Provide input for the post-well directional drilling analysis, and make recommendations for improving the drilling operations on future wells.
9. Be present on the rig floor when the BHA is made up.
10. Ensure proper check on tool face when making up steerable assemblies.
11. Communicate all concerns with responsible parties, including the company man.
Responsibilities at the Prejob Meeting with the Customer

There are a number of items that the directional driller/coordinator should bring to the prejob meeting with the customer. These include:

- Sperry-Sun safety policy
- Sperry-Sun organization chart and contact numbers (telephone, fax, pager, mobile phone)
- Operational specifications (for full service FEMWD/directional only DWD)
- End-of-well report and log format examples (for full service MWD/directional only DWD)
- Resumes of Sperry-Sun field engineers involved in the job
- Copy of the contract and price listing

In addition to the items brought to the prejob meeting, there are a number of things that the directional driller/coordinator must find out during the meeting. These include:

- Safety considerations
- Potential hole problems
- Well information
- Coordinates
- Target specifications
- Well planning information
- Nudging operation
- Well plan scales
- Drilling program and prognosis
- Anti-collision analysis
- Surveys
- Geology
- Drilling equipment needed
- Rig equipment
- Real-time interpretation
- Customer information