references:


• *Directional Drilling and Deviation Control Technology*. French Oil and Gas Industry Association Technical Committee, 1990.
Reasons for Directional Drilling / Deviation Control

1) to reach a planned target area
Reasons for Directional Drilling / Deviation Control

1) to reach a planned target area
Reasons for Directional Drilling / Deviation Control

1) to reach a planned target area
Screwing / Unscrewing Drillpipe

2) to obtain / control a planned hole trajectory

Preventing Hole Deviation
Limiting Crookedness
(Dog Leg Severity)

Dogleg
Abrupt Change
Of Inclination/Azimuth

Measured depth
True vertical depth (TVD)
Target area
Screwing / Unscrewing Drillpipe

3) to sidetrack or abandon a portion of a hole
Classification of Buildup - Rates

<table>
<thead>
<tr>
<th>Classification</th>
<th>Build Rate (°/100 ft)</th>
<th>Radius (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td>2 to 8</td>
<td>2865 to 716</td>
</tr>
<tr>
<td>Medium</td>
<td>8 to 30</td>
<td>716 to 191</td>
</tr>
<tr>
<td>Intermediate</td>
<td>30 to 60</td>
<td>191 to 95</td>
</tr>
<tr>
<td>Short</td>
<td>60 to 200</td>
<td>95 to 28</td>
</tr>
</tbody>
</table>

100 ft = 30,48 m
Measuring the Wellbore Course

A Wellbore Course is a Curve in 3D-Space

Inclination $I_1$
Azimuth $A_1$
Measured Depth $MD_1$

Point 1

$\Delta$ Vert.

3D-Curve is determined by 3 Coordinates
$X=$ West-East
$Y=$ South-North
$Z=$ Vertical Depth

Coordinates must be determined from Measurements between 2 Points of the Hole

Point 2

Inclination $I_2$
Azimuth $A_2$
Measured Depth $MD_2$
Key Seat Buildup in Doglegs

Dogleg Severity (DLS) means CURVATURE of the hole expressed in Degrees / 100 ft. DLS is critical for:
- building of keyseats
- torque and drag
- casing running operation
- running logging sondes
Measurement While Drilling (MWD) Techniques

- Pony sub
- MWD
  - Power pulse
  - D&I (direction and inclination)
  - MVC (magnetic vector compass)
  - Turbine
  - DIWOB (downtorque weight on bit)
  - DTOR (downtorque torque)
  - Battery
  - Gamma ray
- CDR
  - Transmitters
  - Mud channel
  - Receivers
  - Resistivity
- Saver sub
- Float sub/bit sub
- Mill tooth tricone bit
- 16.5 cm (6-1/2"
- 25 cm (9-7/8"
- 11.29 m
- 5.99 m
- 2.71 m
- 14.59 m
- Total length 16.24 m
Why Hole Deviation Occurs?

Equilibrium of Forces at Bit – Cartwheel Analogy

\[ WOB = 0 \]

\[ WOB = F_W \]
Why Hole Deviation Occurs?

Influence of Formation Anisotropy

Basic Assumption
Formations have higher drillability perpendicular to the bedding plane than parallel to it.
Equilibrium Angle dependent on Foliation Dip Angle, Factor of Anisotropy and WOB

Anisotropy Factor \((h)\)

\[
h = \frac{(ROP_\perp - ROP_\parallel)}{ROP_\perp}
\]

- \(h = 0.03\)
- \(h = 0.02\)
- \(h = 0.01\)

Dip Angle of the Foliation

Weight on Bit

- 60 kN
- 40 kN
- 20 kN

Calculated for 6"-Borehole
Controlling Hole Inclination by Bottom Hole Assembly (BHA)

BHA = Assembly of Drill Collars and Stabilizers

- Packed (Angle-Holding) Assembly:
  - 20 to 30 ft
  - 10 to 20 ft
  - 5 to 10 ft

- Pendulum (Angle-Dropping) Assembly:
  - 20 to 30 ft
  - 30 to 90 ft

- Fulcrum (Angle-Building) Assembly:
  - 3 to 8 ft
# Basic Types of Stabilizing Tools

<table>
<thead>
<tr>
<th>ROTATING BLADE</th>
<th>NON-ROTATING</th>
<th>REAMER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spiral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short</td>
<td></td>
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<tr>
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</tr>
<tr>
<td>Long</td>
<td></td>
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</tr>
</tbody>
</table>
Controlling Hole Inclination with Adjustable Stabilizers

Diagram showing the use of adjustable stabilizers to control hole inclination.
Controlling Wellbore Trajectory with Steerable DHM

AKO/ABS Motor
- Bit Offset Device: Adjustable Kick-Off Sub and Adjustable Bent Sub
- Power Section: Navi-Drill Mach 1
- Build Rates: 10° to 24°/100 ft (30 m)

AKO Steerable Motor
- Bit Offset Device: Rigsite Adjustable Kick-Off Sub
- Power Section: Navi-Drill Mach 1 or Mach 2
- Build Rates: 1° to 4°/100 ft (30 m)

DTU Steerable Motor
- Bit Offset Device: Double-Tilted U-Joint Housing
- Power Section: Navi-Drill Mach 1 or Mach 2
- Build Rates: 1° to 4°/100 ft (30 m)
Positive Displacement Motor (PDM)

- Characteristics of PDM:
  - Low – Medium RPM
  - High Torque
  - Ideal for Roller Cone Bits

Turbine Type Motor

- Characteristics of Turbines:
  - High RPM
  - Ideal for Diamond Bits
Positive Displacement Motor Components

- Coupling
- Stabilizer
- Driveshaft
- Bearing Pack
- Adjustable Bent Housing
- Dump Valve
- Power Section
Performance Characteristic of Drilling Turbines

- 7-3/4" DIRECTIONAL TURBODRILL
- 19'-4" LENGTH
- 500 GAL/MIN FLOW RATE
- 10 LB/GAL MUD

**Power and Rotational Speed**
Slow down when high torque is required

**Stalling Torque**

![Graph showing the relationship between torque, power, and rotational speed for a drilling turbine.](image)
Directional Drilling with DHM – Steering Systems

Motor Steering System MSS-6-12 with DIMA and Bent Sub for Directional Drilling

- Stabilizer
- Flexible Non-Magnetic Drill Collar
- Magnetometer (MA)
- Bent Sub
- Mud Pulser
- Drift Indicator (DI)
- Downhole Motor
- Steering Rib
- Stabilizer Pad (exchangeable)
- Drill Bit
Open Hole and Cased Hole Sidetracking with a Cement Plug
Sidetracking with Oriented Whipstock Technique
A "Sleep-well" Mattress will give you at least ten years of luxurious, healthful sleep. Rolled edges, top and bottom—four rounded corners—tighter buttoning—and pure sterilised fillings—the "Sleep-well" will always keep its shape, will last longer, and will prove the most economical in the long run. Obtainable at leading drapers and furnishers, from £3 10s. 0d. to £6 6s. 0d., full size.

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ARTHUR ELLIS & CO. Ltd., Woolmead Manufacturers, DUNEDIN