4. Deflection Tools and Technique

4.1 Whipstocks
4.2 Jetting
4.3 Downhole motor with bent sub
4.4 Downhole motor with bent housing
4.5 Steerable Motor Assemblies
4.6 Rotary Steerable Systems
4. Deflection Tools and Technique

Whipstocks – main deflection tool in 1930-1950

Jetting – technique was developed in mid-1950s

Downhole motors with bent sub – superseded whipstocks and jetting

Most commonly used today:

- Downhole motors with fixed bent housing
- Steerable motor assemblies with adjustable bent housing
- Rotary steerable systems
4.1 Whipstocks

1 – Standard Removable Whipstock
is used to kick off wells

2 – Circulating Whipstock
permits more efficient cleaning
of the bottom

3 – Casing Whipstock
is used where a “window” is to
be cut in casing for sidetracking

4.1 Standard Removable Whipstock

Courtesy: French Oil & Gas Industry Association

1 – Lowering and orientating whipstock assembly

2 – Drilling the rat hole. Pulling whipstock out of the hole

3 – Running the hole opener assembly

4.1 Standard Removable Whipstock

Advantages:
- Simple equipment
- Requires little maintenance
- No temperature limitations

Disadvantages:
- Large number of trips for kick-off (at least three)
- Produces high initial DLS (dogleg severity)
Jetting is a technique used to deviate wellbores in soft formations.
4.2 Procedure for Jetting

Courtesy: French Oil & Gas Industry Association

1 – Jetting
2 – Spudding
3 – Drilling

4.2 Jetting

Requirements for jetting:

• A special jet bit or standard soft formation tri-cone bit, with one very large nozzle and two smaller ones can be used.

• The formations must be soft enough (penetration rates of greater than 80 ft/hr using normal drilling parameters) to be suitable for jetting.

• Adequate rig hydraulic horsepower must be available (mud velocity through the large jet should be at least 500 ft/sec).
4.3 Downhole Motor with Bent Sub

- Downhole motor with bent sub may be used for:
  - kicking off wells
  - correction runs
  - sidetracking

- Bent sub is placed directly above the motor

4.3 Bent Sub

- Bent sub’s lower thread (on the pin) is inclined 1° - 3° from the axis of the sub body
- Dogleg severity (DLS) depends on:
  - Bent sub angle
  - OD of motor, bent sub, and drill collars
  - Length of motor
  - Hole diameter
- Usually DLS = 1° - 2°/10m (10° - 20°/30ft)
4.4 Downhole Motor with Bent Housing

Courtesy: Baker Hughes

4.4 Turbine with Bent Housing

Crafts: Neyrfor Turbodrill

Drive Shaft
Turbine Section Body
Turbine Stages
Flexible Drive Shaft
Lower Bearing
Bit
Thrust Bearing
Lower Stabilizer
Replaceable Stabilizer
Bent Housing

Bent housing is more effective than the bent sub because of a shorter bit to bend distance, which:

- Reduces the bit offset
- Creates a higher build rate for a given bend angle
- Reduces the moment arm
- Reduces the bending stress at the bend
- Allows assembly easier to orient
4.5 Steerable Motor Assemblies

Steerable Motor Assemblies are used in two modes:

- Oriented (non-rotational) mode – for drilling a curved path
- Rotary mode – for drilling a straight path

Benefits:

- Elimination of trips for directional assembly changes, saving rig time
- More complex well paths can be drilled
- Wells are drilled more closely to the plan at all times
4.5 Steerable Motor Assemblies

**DTU** – Double Tilted U-joint Housing

**ABH** – Adjustable Bent Housing

4.5 Adjustable Bent Housing (ABH)
4.5 Downhole Motor with ABH

Benefits:

• Bent angle easily can be changed by drilling crew on a rig floor
• Shorter bit to bent distance (between bearing and motor sections)
• Wider variety of DLS from 0 (tangent section) to 4 degrees/30 ft
• Possibility to use in two modes: oriented and rotary
• MWD system allows continual control on borehole trajectory and high accuracy of bent housing orientation
4.5 Downhole Motor with ABH

Rotation of the drill string while drilling with downhole motor and adjustable bent housing (ABH):

- Negates the effect of bit tilt and allows to drill the straight hole
- Drills slightly oversize hole
- Decreases the risk of stuck pipe
- Improves hole cleaning
- Decreases friction between drill string and borehole
- Increases ROP due to higher power at bit
4.5 Maximum Recommended Bend Angle for Rotary Mode (Speeds up to 100 RPM)

*Courtesy: Tomahawk Downhole*

<table>
<thead>
<tr>
<th>6-⅜” Down Hole Motor</th>
<th>Hole Size, inch</th>
<th>Maximum Bend, degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Slick</strong></td>
<td>7-7/8</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>8-1/2</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>8-3/4</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>9-7/8</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Partially Stabilized</strong></td>
<td>7-7/8</td>
<td>1.25</td>
</tr>
<tr>
<td>Motor has a 1/8” under gauge near-bit stabilizer</td>
<td>8-1/2</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>8-3/4</td>
<td>1.75</td>
</tr>
<tr>
<td></td>
<td>9-7/8</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Fully Stabilized</strong></td>
<td>7-7/8</td>
<td>1.25</td>
</tr>
<tr>
<td>Motor has a 1/8” under gauge near-bit stabilizer and a 1/8” under gauge top stabilizer above the motor</td>
<td>8-1/2</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>8-3/4</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>9-7/8</td>
<td>1.25</td>
</tr>
</tbody>
</table>

4.5 Bit Offset

Courtesy: Short. Directional & Horizontal Drilling

DTU  Bent Sub  Bent Sub & Bent Housing

4.5 Theoretical Build Rates
“Three-Point-Curvature” Calculations

\[ i = 200 \frac{\theta}{L_1 + L_2} \]

- \( i \) – build rate, deg/100ft
- \( \theta \) – bent angle, deg
- \( L_1 \) – distance from bit to bent housing, ft
- \( L_2 \) – distance from bent housing to motor top stabilizer, ft
# 4.5 Build Rates (deg/100ft) for 6-3/4” Mud Motor

**Courtesy: Tomahawk Downhole**

<table>
<thead>
<tr>
<th>Angle (deg)</th>
<th>Hole Size (in) – Slick Sleeve</th>
<th>Hole Size (in) – Stabilized</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7-7/8</td>
<td>8-1/2</td>
</tr>
<tr>
<td>0.50</td>
<td>0.82</td>
<td>0.93</td>
</tr>
<tr>
<td>0.75</td>
<td>2.80</td>
<td>1.05</td>
</tr>
<tr>
<td>1.00</td>
<td>4.78</td>
<td>3.03</td>
</tr>
<tr>
<td>1.25</td>
<td>6.76</td>
<td>5.02</td>
</tr>
<tr>
<td>1.50</td>
<td>8.74</td>
<td>7.00</td>
</tr>
<tr>
<td>1.75</td>
<td>10.72</td>
<td>8.98</td>
</tr>
<tr>
<td>2.00</td>
<td>12.70</td>
<td>10.96</td>
</tr>
<tr>
<td>2.50</td>
<td>16.67</td>
<td>14.92</td>
</tr>
<tr>
<td>2.75</td>
<td>18.65</td>
<td>16.90</td>
</tr>
<tr>
<td>3.00</td>
<td>20.63</td>
<td>18.88</td>
</tr>
</tbody>
</table>

4.6 Rotary Steerable Systems

- Auto Trak (Baker Hughes)
- Power Drive (Schlumberger)
- Geo-Pilot (Halliburton)
4.6 AutoTrak

Courtesy: Baker Hughes

4.6 AutoTrak

Courtesy: Baker Hughes
4.6 Power Drive

Courtesy: Schlumberger
4.6 Power Drive Steering Unit

Courtesy: Schlumberger
4.6 Rotary Steerable Systems

- Deliver consistent steering and high ROP
- Improve hole quality by reducing tortuosity
- Reduce torque and drag due to continuous string rotation
- Better hole cleaning and less clean up time
- Recommended for use in offshore and extended reach applications