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5. Drilling activities

5.1 General
This clause section covers requirements and guidelines pertaining to well integrity during drilling activities and operations including through tubing drilling.

The activity starts with spudding of the well and concludes with preparation for completion or testing activities or well for sidetracking, suspension or abandonment.

The purpose of this clause section is to describe the establishment of well barriers by use of WBEs well barrier elements and additional features required to execute this activity in a safe manner.

5.2 Well barrier schematics
It is recommended that WBSs are developed as a practical method to demonstrate and illustrate the presence of the defined primary and secondary well barriers in the well, see 4.2.

In the table below some typical scenarios are listed including references to attached illustrations. The table is not comprehensive and Well barrier schematics (WBS) shall be prepared for the actual situations during an each well activity or operation should be made.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Comments</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drilling, coring and tripping with shearable drill string.</td>
<td></td>
<td>5.8.1</td>
</tr>
<tr>
<td>2</td>
<td>Running non-shearable drill string.</td>
<td></td>
<td>5.8.2</td>
</tr>
<tr>
<td>3</td>
<td>Running non-shearable casing.</td>
<td></td>
<td>5.8.3</td>
</tr>
<tr>
<td>4</td>
<td>Through tubing drilling and coring.</td>
<td></td>
<td>5.8.4</td>
</tr>
<tr>
<td>5</td>
<td>Pipe conveyed wireline logging.</td>
<td></td>
<td>10.8.5</td>
</tr>
</tbody>
</table>

Samples of well barrier schematics for selected situations are presented at the end of this section (5.8).

5.3 Well barrier acceptance criteria
The following list defines specific requirements and guidelines applying for well barriers:

a) Drilling of top hole can be conducted with the fluid column as the only well barrier. Potential shallow gas zones should not be penetrated.

b) Prior to drilling out of the surface casing, a drilling BOP shall be installed.

c) Prior to drilling the lateral bore in a multi-lateral well, well control action procedures shall be established for controlling influxes from any of the previously drilled bores.

d) Floating (partially filled up) of non-shearable tubular strings in open hole or with open perforations exposed should be conducted with two qualified WBEs well barrier elements located inside the tubular. The inside WBEs well barrier elements shall be designed such that fluid can be circulated.

e) For shallow gas zones, one well barrier element external to the surface casing (Casing Cement) is acceptable, providing:

• The surface casing shoe is pressure tested to a pressure higher than the pressure in the shallow gas zone.
• The surface casing cement has been logged with minimum 30 mMD of good bonding above the top of the shallow gas zone.
5.4 Well barrier elements acceptance criteria

5.4.1 General
Subclause 5.8 lists the WBEs that constitute the primary and secondary well barriers for situations that are illustrated.

5.4.2 Additional well barrier elements (WBEs) acceptance criteria
The following table describes features, requirements and guidelines which are additional to what is described in Clause Section 15.
Table 1

<table>
<thead>
<tr>
<th>No. Table no.</th>
<th>Element name</th>
<th>Additional features, requirements and guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fluid column</td>
<td>Riser margin (only applicable for vessels with a marine riser)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The fluid column is not a qualified well barrier when the marine riser has been disconnected. Planned or accidental disconnect of the marine riser, resulting in loss of the fluid well barrier shall be planned accounted for. Procedures for planning and implementation of compensating measures shall be established.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If the uncased borehole has penetrated hydrocarbon bearing formations or abnormally pressured formations with a flow potential and the hydrostatic pressure in the well with the riser disconnected may become less than or equal to the pore/reservoir pressure of these formations, risk reducing measures shall be established with the following priority:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A. reduce the probability of having an influx during the disconnect period</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. strengthen the availability/reliability of the remaining well barrier.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The following table is listing some examples of risk reducing measures that could be applied.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Priority</th>
<th>Risk reducing measure</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Drill with “Riser Margin”</td>
<td>Maintain a drilling fluid density that will provide an overbalance with the marine riser disconnected. This alternative shall be assessed as the primary compensating measure.</td>
</tr>
<tr>
<td>A</td>
<td>Spot a weighted fluid</td>
<td>Displace the entire well or part of the well to a fluid with a density that will provide an overbalance towards zones with a flow potential with the marine riser disconnected.</td>
</tr>
<tr>
<td>B</td>
<td>Install a bridge plug</td>
<td>Install a bridge plug with storm valve below the wellhead.</td>
</tr>
<tr>
<td>B</td>
<td>Two shear-seal rams</td>
<td>Use two shear-seal rams in the drilling BOP as an extra seal element during hang-off / drive-off situations.</td>
</tr>
</tbody>
</table>

2 | BOP | A risk analysis shall be performed to decide the best BOP configuration for the location. The risk analysis should take the following into account: |
|    |    | a) Position of different ram types |
|    |    | b) Choke and kill line access position |
|    |    | c) Ability to hang off pipe and retain ability to close shear ram, including contingency closure of rams if available |
|    |    | d) Ability to centralize pipe prior to closing shear ram |
|    |    | e) Back-up shear ram |
In order to achieve effective placement and qualification of the casing cement the following factors should be addressed:

a) Centralization / stand-off
b) Use of fluid spacers
c) The cement shall be lab tested under well conditions with conclusive and documented results, giving specified hardening time and compressive strength
d) Effect of hydrostatic pressure differentials inside and outside casing during pumping of cement and when cement sets
e) Length of shoetrack (see table 15.24)

If the return is different from the calculated volume, or the top of cement is inconclusive a bond log shall be run for all cement sections serving as a barrier element.

Cement should be left undisturbed after placement until it has reached sufficient compressive strength.

The shoe track shall not be used as a well barrier element if the bleed back volume from placement of casing cement exceeds the calculated volume to depressurize the drill pipe internal pressure.

5.4.3 Common well barrier elements (WBEs)
There are no identified common WBEs in 5.2.

5.5 Well control action procedures and drills

5.5.1 Well control action procedures
The following table describes incident scenarios for which well control action procedures should be available (if applicable) to deal with the incidents should they occur. This list is not comprehensive and additional scenarios may be included based on the actual planned activity, see 4.2.7 activities.
### Item Description Comments

1. Shallow gas influx.

2. Influx occurring with shearable pipe or tools through the BOP. **Include plan to centralize pipe before shear.**

3. Influx occurring with non-shearable pipe or tools through the BOP.

4. Influx containing H2S.

5. **Influx from any of the previously drilled lateral wellbores** **Drilling the lateral bore in a multi-lateral well**

#### 5.5.2 Well control action drills

The following well control action drills should be performed:

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
<th>Objective</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow gas kick drill</td>
<td>Once per well with crew on tour.</td>
<td>Response training to shallow gas influx.</td>
<td>To be done prior to drilling surface hole or pilot hole.</td>
</tr>
<tr>
<td>Kick drill - drilling</td>
<td>Once per week per crew.</td>
<td>Response training to an influx while drilling (bit on bottom).</td>
<td></td>
</tr>
<tr>
<td>Kick drill - tripping</td>
<td>Once per week per crew.</td>
<td>Response training to an influx while tripping (bit off bottom).</td>
<td>Practice centralizing to prepare for shearing pipe.</td>
</tr>
<tr>
<td>Choke drill</td>
<td>Once per well with crew on tour.</td>
<td>Practice in operating the remotely operated choke with pressure in the well.</td>
<td>Before drilling out of the last casing set above a prospective reservoir. For subsea BOP: Include the scenario of flowing well with gas on drill floor as a table top exercise. Should include the steps of lining up diverter to overboard lines and effect of gas on drill floor.</td>
</tr>
<tr>
<td>H2S drill</td>
<td>Prior to drilling into a potential H2S zone/reservoir.</td>
<td>Practice in use of respiratory equipment.</td>
<td></td>
</tr>
<tr>
<td><strong>Subsea BOP:</strong> BOP on deck drill</td>
<td><strong>Every time BOP is on deck.</strong></td>
<td><strong>Operate BOP panels.</strong></td>
<td>Include the latter steps of the Choke drill with handling of emergency situation with gas on drill floor. For dynamically positioned rigs the scenario should include communication from the bridge to drill floor and operate the emergency disconnect sequence.</td>
</tr>
</tbody>
</table>
**5.6 Casing design**

**5.6.1 General**

All components of the casing string including connections, circulation devices and landing string shall be subject to load case verification.

Casing, liner and tieback-strings shall be designed to withstand all planned and/or expected loads and stresses including those induced during potential well control situations.

The weakest points in the string with regards to design process shall cover the complete well or section lifespan encompassing all stages from installation to burst, collapse and tensile strength rating, permanent plugging and abandonment and include effects of goods deterioration.

Design basis and margins shall be clearly known and documented.

Weak-points shall be identified and documented.

All casing strings that are part of a well barrier in subsequent phases shall be logged for wear after drilling if simulation shows risk of wear close to maximum allowed wear.

For through tubing drilling operations, where all or parts of the completion string will serve as a well barrier element at any stage, the tubing and all relevant accessories shall be reclassified to production casing and be redesigned/re-qualified to meet relevant drilling loads.

**5.6.2 Design basis, premises and assumptions**

The following data should be used to establish the dimensioning parameters for the addressed in the design process. Experience from previous wells in the area or similar wells shall be assessed:

a) Planned well trajectory and bending stresses induced by doglegs and hole curvature.
b) Maximum allowable setting depth with regards to kick margin.
c) Estimated pore pressure development.
d) Estimated formation integrity.
e) Estimated temperature gradient.
f) Drilling fluids and cement program.
g) Loads induced by well services and operations.
h) Completion design requirements.
i) Estimated casing wear.
j) Setting depth restrictions due to formation evaluation requirements.
k) Potential for H2S and/or CO2.
l) Metallurgical considerations.
m) Well abandonment requirements.
n) ECD and surge/swab effects due to narrow annulus clearances.
5.6.3 Load cases

When designing for burst, collapse and axial loads, the following load cases shall minimum be considered. This list is not comprehensive and load cases applicable for the planned activity shall be applied. Possible changes in design loads and stresses during the life expectancy of the well shall be assessed.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Gas kick.</td>
<td>Size/volume and intensity to be defined.</td>
</tr>
<tr>
<td>2.</td>
<td>Gas filled casing (floating installations).</td>
<td>Applicable to last casing above the reservoir and subsequent casings.</td>
</tr>
<tr>
<td>3.</td>
<td>Production and/or Injection tubing leaks.</td>
<td>Based on METP. See 7.7.2 for multipurpose wells.</td>
</tr>
<tr>
<td>5.</td>
<td>Leak testing casing.</td>
<td>See 7.7.2 for multipurpose wells.</td>
</tr>
<tr>
<td>7.</td>
<td>Dynamic loads from running of casing, including over pull to free stuck casing.</td>
<td></td>
</tr>
</tbody>
</table>

5.6.4 Minimum design factors

For deterministic calculations of loads and ratings, these factors should apply:

As an alternative to the above design factors, stress design or stress verification programs might be employed to demonstrate the presence of appropriate design factor(s). Minimum design factors for burst, collapse and tri-axial loads. The following factors should apply:

- **Burst**: 1.10
- **Collapse**: 1.0
- **Tension**: 1.3
- **Tri-axial**: 1.25

5.6.5 Conductor design

The conductor shall be designed to give adequate structural support to the wellhead and all tubulars installed during the expected lifespan of the well. An analysis shall be performed to confirm the ability to withstand any loads the conductor may be exposed to.

The conductor analysis shall address the following:

- Extreme weather conditions with an appropriate return period
- Vortex induced stress/capacity vibrations
c) For probabilistic calculations of loads and ratings, the probability of failure should be less than $10^{-3.5}$.

d) Corrosion

e) Marine growth

5.7 Other topics

5.7.1 Drilling location

A site survey shall be performed and interpreted to identify water depth, seabed and sub-surface hazards at the intended well location and relief well locations. The survey can be performed with means of sonar equipment and direct visual observations. Sea bed topography, anchor holding capabilities, presence of boulders, cables, pipelines and other obstructions should be assessed.

Well locations shall be selected where the risk associated with shallow gas is acceptable.

The seismic lines shall have a penetration covering the geological sequence to the setting depth for the surface casing.

Soil tests should be available for intended deep water and jack-up drilling locations.

5.7.2 Shallow gas

5.7.2.1 General

The risk of drilling into shallow gas shall be assessed for all wells together with risk reducing measures.
The risk assessment shall be based on

- interpretation of data from relevant offset wells, and
- interpretation of the shallow seismic survey at the indented well location.

The following shall be established:

a) A model/procedure for defining the risk of shallow gas and operational constraints.

b) Criteria for drilling a pilot hole and when to drill with riser/diverter/mud recovery system installed.

c) Operational procedures and well control action procedures for drilling through potential shallow gas zones with focus on risk reducing measures.

d) Selection of alternate drilling locations.

5.7.2.2 Shallow gas risk assessment model

The following should be evaluated to determine the probability of classified as a potential shallow gas well if any of the following applies:

a) Whether relevant offset well exists

b) Shallow gas is detected in relevant offset wells and in the same formations that will be penetrated in the well.

c) Whether a structural closure is seen on the seismic that could trap shallow gas.

d) Whether there are anomalies on the seismic interpretation that could indicate presence of gas.

If the answer to minimum one of the criteria above is yes, the well shall be classified as a potential shallow gas well.

The consequence of drilling through shallow gas zones should be evaluated concerning drilling

- with semi submersible/drill ship or jack-up/platform, regards to type of drilling rig.

- Water depth less or more than 100 m.

- Drilling with or without riser, or other means of mud recovery.

- Wind and current conditions while drilling.

5.7.2.3 Operational constraints

The following operational constraints are applicable for a potential shallow gas well:

a) The well location shall if possible be moved if consequence and/or probability of shallow gas is high.

b) A pilot hole with a diameter that allows the well to be killed dynamically shall be drilled through all potential shallow gas zones.

c) Predicted shallow gas zones with abnormal pressured zones pressure shall be drilled with weighted drilling fluid.

da) It shall be possible to kill the pilot hole dynamically

d) A float valve without an orifice should be installed in the BHA.

e) The potential shallow gas zones should be logged with LWD gamma ray resistivity.

f) Returns from the borehole shall be observed with ROV camera or remote camera.

- Kill fluid shall be available until the pilot hole has been opened.

- Cementing materials shall be on board location to set a 50 m long gas tight cement plug in the pilot hole with 200 % excess.

- Plans and materials for setting surface casing above a shallow gas zone should be prepared.
The following operational constraints shall be observed if there is no potential for shallow water.

If no gas and a pilot hole is planned for water depth less than 100 m, regardless of how remote the probability of encountering shallow gas might be, and not drilled, a drilling facility impact assessment shall be performed with respect to shallow gas influx in cases where the water depth is less than 100 m.

5.7.3 Geo pressure estimation

Estimation of pore pressure shall commence after drilling out of the surface casing and formation fracture pressure shall be prepared and should be estimated regularly when updated as new formation is drilled.

The methods and techniques for estimating the pore pressure shall be described. The risk of a change in pore pressure compared to the original pore pressure due to injection of cuttings and slop in other wells shall be assessed.

5.7.4 Well trajectory measurements and anti-collision monitoring

5.7.4.1 General

Precise determination of the well path is important to:

a) avoid penetrating another well,
b) facilitate intersection of the well bore with a relief well (blow-out),
c) facilitate geological modeling.

5.7.4.2 Well trajectory measurements

The following apply:

a) The surface location coordinates of the well bore centre shall be determined with use of differential global positioning system. Well slot co-ordinates can be established by measurements from a known reference point (fixed point on a platform, subsea template, etc.).
b) During drilling of new formation, measurement of well bore inclination and direction shall be obtained at least every 100 m MD. All survey plots should be referenced to grid north.
c) The position of the well bore being drilled (reference well) and the distance to adjacent wells (object well) shall be known at all times. The minimum curvature method or other equivalent models should be used.

5.7.4.3 Model and acceptance criteria for separation between well bores

d) A model for quantifying the uncertainty shall be established. The probability for the well bore to be within the calculated uncertainty ellipses should exceed 95%.
e) Minimum acceptable separation distance between well bores and risk reducing actions shall be defined.

5.7.4.4 Model and acceptance criteria for separation between well bores

The following model can be used to define minimum acceptable separation:

$$SF = \frac{D}{(Er + Eo + Rr + Ro)}$$

where:

$SF$ = separation factor
$Er$ = ellipse radius of reference well (well being drilled) in the direction of the object well
$Eo$ = ellipse radius of the object well (neighbouring well) in the direction of the reference well
$Rr$ = bit radius of reference well
Ro = casing radius in the object well
D = computed distance between the centre of reference well and centre of the object well.

The table below describes recommended actions to be taken for SF < 1,0 if the model indicates that the separation between wellbores is less than the minimum acceptable separation:

<table>
<thead>
<tr>
<th>Point of potential contact</th>
<th>Recommended action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casing with no well barrier function.</td>
<td>The cuttings from the reference well should be <strong>analyzed</strong> to determine cement and/or metal content prior to exceeding the SF (base line) the separation between wellbores becoming less than the minimum acceptable separation and when drilling within this range. The casing by casing annuli in <strong>object adjacent</strong> well(s) with access to the point of potential contact should be pressurised and monitored for changes in pressure in case there is penetration by the drill bit. If this is not possible, alternative methods such as noise detection should be used.</td>
</tr>
<tr>
<td>Casing with a function as secondary well barrier or production liner.</td>
<td>As above, and: The production/injection of the object adjacent well(s) should cease, and the object adjacent well(s) should be secured by closing of the SCSSV/ASCSSV, or setting tubing plugs, bridge plugs, or cement plugs. Installation of a well barrier below the estimated point of contact shall be assessed.</td>
</tr>
</tbody>
</table>

5.7.5 Through tubing drilling activities

Through tubing drilling activities shall be regarded as alterations to an existing well and hence a new design basis shall be established. A new well design process shall be carried out on the revised design basis/premises, see 4.3 and 5.6.

All primary and secondary **WBEs - well barrier elements** shall be verified to meet the new design loads prior to commencing operation.

Special considerations shall be put on protection of elements not normally well barrier elements that are exposed to drilling loads (production tree, tubing, SCSSV/HSV, etc.). These elements shall either be protected against the loads (i.e. by installing wear sleeve/bushing in SCSSV/HSV and/or production tree) or be verified capable of resisting the defined loads. Calculations documenting acceptance of the new loads and/or mitigations to reduce/eliminate loads should be verified by supplier and if critical, by an independent expert.

If through tubing drilling is performed in UB/CT/snubbing mode, the relevant sections of this NORSOK standard describing these operations shall be adhered to, see **Clause Section 11, Clause Section 12 and Clause Section 13**.
### 5.8 Well Examples of well barrier schematic illustrations

#### 5.8.1 Drilling, coring and tripping with shearable drill string

<table>
<thead>
<tr>
<th>Well barrier elements</th>
<th>See Table</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary well barrier</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Fluid column</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><strong>Secondary well barrier</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Casing cement</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>2. Casing</td>
<td>2</td>
<td>Last casing set</td>
</tr>
<tr>
<td>3. Wellhead</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4. High pressure riser</td>
<td>26</td>
<td>If installed</td>
</tr>
<tr>
<td>5. Drilling BOP</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

**Note**
- None
### 5.8.2 Running non-shearable drill string

<table>
<thead>
<tr>
<th>Well barrier elements</th>
<th>See Table</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary well barrier</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Fluid column</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Secondary well barrier</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Casing cement</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>2. Casing</td>
<td>2</td>
<td><strong>Last casing set</strong></td>
</tr>
<tr>
<td>3. Wellhead</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4. High pressure riser</td>
<td>26</td>
<td><strong>If installed</strong></td>
</tr>
<tr>
<td>5. Drilling BOP</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>6. Drill string</td>
<td>3</td>
<td><strong>Drill collars and BHA</strong></td>
</tr>
<tr>
<td>7. Stab-in safety valve</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

**Note**

None
5.8.3 Running non-shearable casing
<table>
<thead>
<tr>
<th>Well barrier elements</th>
<th>See Table</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary well barrier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Fluid column</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Secondary well barrier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Casing cement</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>2. Casing</td>
<td>2</td>
<td>Last casing set.</td>
</tr>
<tr>
<td>3. Wellhead</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4. High pressure riser</td>
<td>26</td>
<td>If installed.</td>
</tr>
<tr>
<td>5. Drilling BOP</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>6. Casing</td>
<td>2</td>
<td>See NOTE</td>
</tr>
<tr>
<td>7. Casing float valves</td>
<td>41</td>
<td></td>
</tr>
</tbody>
</table>

Note
The criteria for accepting casing as WBE during running of casing without prior leak testing of each connection are:

1. Pipe body and connections are designed to withstand defined loads.
2. Casing is manufactured according to accepted standards.
3. Connections are inspected and made up according to established procedures.
4. Stab in safety valve is readily available on the drill floor.
5.8.4 Through tubing drilling and coring
**Well barrier elements** | **See** | **Additional features, requirements and guidelines**
---|---|---
**Primary barrier**
1. Fluid column | Table 1

**Secondary barrier**
1. Casing | Table 2
2. Casing cement | Table 22
3. Wellhead | Table 5
4. Tubing hanger | Table 10
5. Production tree | Table 31
6. Production tree | Table 33
6. High pressure riser | Table 26
Between surface production tree and drilling BOP
7. Drilling BOP | Table 4
Shear-seal rams
8. Annulus access line and valve | Table 12

**NOTE**

1. **Non**

The following well barrier schematics are guidelines and describe one possible solution for how the well barrier envelopes with well barrier elements can be established and illustrated.

**HOLD: Insert new WBS here**