

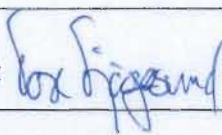


# Evaluation of well barriers in Temporary abandoned wells

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# 1 Introduction

Sintef Petroleumsforskning is undertaking an evaluation of the temporary abandoned wells on the Norwegian continental shelf.

Wellbarrier has been requested to perform an evaluation of the well barrier definition as presented in 11 Well Barrier Schematics provided by 8 different operating companies. The evaluation shall consider the following:

- Compliance with PSA (Petroleum Safety Authority) Safety regulation, Facilities and Activity regulations in particular.
- Compliance with Norsok D-010 rev. 3 Well integrity in drilling and well operations.
- Compliance with OLF Guideline 117
- Comment to the well barrier definitions as presented.

It should be noted that the evaluation is done based on a selection of barrier illustrations and supporting documents provided by Sintef:

- Well barrier schematic
- PSA reporting table "Status of Temporary Abandoned Wells"
- Risk evaluation forms provided by some of the operators

In the assessment of the material we have reviewed the well barrier schematics and commented where we have identified deviations from regulations, Norsok D-010 and the OLF guideline 117 section 3.3.

## 2 Regulatory (and Norsok D-010 indirect) requirement:

The PSA safety regulation does not explicitly state that there shall be two well barriers preventing flow to surface, although this is presumed to be the intention. The guideline to the PSA safety regulation does make a reference to Norsok D-010 rev. 3 which states that two well barriers are required. However the PSA guideline is not mandatory and the Operator may claim other “equally” safe methods.

The relevant references are listed below, (the **bold** is made to highlight key phrases):

Reference	Description
Management regulation §5 Barriers	Barriers shall be established that a) reduce the probability of failures and hazard and accident situations developing. b) limit possible harm and disadvantages. Where more than one barrier is necessary, there shall be <b>sufficient independence</b> between barriers. The operator or the party responsible for operation of an offshore or onshore facility, shall stipulate the strategies and principles that form the basis for design, use and maintenance of barriers, so that the barriers’ function is safeguarded throughout the offshore or onshore facility’s life. Personnel shall be aware of <b>what barriers have been established and which function they are intended to fulfil. ...</b>
Management regulation Guideline to §5 Barriers	Barriers as mentioned in the first subsection, can consist of either physical or non-physical measures, or a combination. The requirement for independence as mentioned in the second subsection, means that it should not be possible for multiple to be impaired or malfunction simultaneously, e.g as a result of a single fault or a single incident. <b>..... be designed so that they contribute to provide all of the involved parties with a common understanding</b> of the requirements for the individual barriers, including the connection between risk and hazard assessments and the requirements for and relating to barriers. ....
Facilities regulation §48 Well barriers	... Well barriers shall be designed such that unintended well influx and outflow to the external environment is prevented, and such that they do not hinder well activities. ....
Facilities regulation Guideline to §48 Well barriers	... In order to fulfil the requirement regarding well barriers, the <a href="#">NORSOK D-010</a> standard <b>Chapters 4.2.1, 4.2.3, 5.6, 9 and 15</b> should be used in the area of health, working environment and safety. ...
Activity regulation §88 Securing wells	<b>All wells shall be secured before they are abandoned</b> so that well integrity is safeguarded during the time they are abandoned, cf. <a href="#">Section 48 of the Facilities Regulations</a> . For <b>subsea-completed wells</b> , well integrity <b>shall be monitored if the plan is to abandon the wells for more than twelve months</b> . It shall be <b>possible to check well integrity in the event of reconnection</b> on temporarily abandoned wells. ....
Activity regulation Guideline to §88 Securing wells	To fulfil the requirement relating to securing as mentioned in the first subsection, the <a href="#">NORSOK D-010</a> standard, <b>Chapter 9 should be used</b> in the area of health, working environment and safety. The monitoring as mentioned in the first subsection, should be carried out by <b>monitoring the pressure above the lowermost barrier</b> . In order to control the well integrity as mentioned in the second subsection, one should, inter alia, <b>be able to monitor pressure conditions or set a blind plug just above or below the packer element</b> . For surface-completed wells, it should be <b>possible to monitor the pressure in the annulus and in the production tubing</b> , or as an alternative, in the last casing set. For subsea-completed wells, it should be <b>possible to monitor the pressure in the production tubing and in the production annulus. ....</b>
Norsok D-010, 4.2.3.2 Function and number of well barriers	There <b>shall be two well barriers</b> available during all well activities and operations, <b>including suspended or abandoned wells</b> , where a pressure differential exists that may cause uncontrolled outflow from the borehole/well to the external environment.
Norsok D-010, 4.2.3.3 Well barrier design, selection and construction principles	.... The primary and secondary well barriers shall to the extent possible <b>be independent</b> of each other without common WBEs. If <b>common WBEs exist, a risk analysis shall be performed and risk reducing/mitigating measures applied</b> to reduce the risk as low as reasonably practicable.

Beware that the above descriptions are only selected extracts from the full paragraph descriptions.

### 3 Norsok D-010 requirement:

- Norsok clearly specify the requirement to two independent well barriers (4.2.3.2).
- Well barriers should be installed as close to the potential source of inflow as possible, covering all possible leak paths.  
The primary and secondary well barriers shall be positioned at a depth where the estimated formation fracture pressure at the base of the plug is in excess of the potential internal pressure. (9.3.2)
- The materials used in well barriers for plugging of wells shall withstand the load/ environmental conditions it may be exposed to for the time the well will be abandoned. Tests should be performed to document long term integrity of plugging materials used. (9.3.3)
- When inflow testing or leak testing from above to verify the integrity of a well barrier is not possible, or when this may not give conclusive results, other means of ensuring proper installation of a well barrier shall be used. Verification through assessment of job planning and actual job performance parameters are options available. (9.3.4)
- It shall be possible to re-enter temporarily abandoned wells in a safe manner. Integrity of materials used for temporary abandonment should be ensured for the planned abandonment period times two. Hence, a mechanical well barrier may be acceptable for temporary abandonment, subject to type, planned abandonment period and subsurface environment.  
Degradation of casing body should be considered for longer temporary abandonment scenarios. (9.3.7.) (also 15.28 for mechanical tubular plugs)
- A cement plug installed using a pressure tested mechanical plug as a foundation should be verified by documenting the strength development using a sample slurry subjected to an ultrasonic compressive strength analysis or one that have been tested under representative temperature and/or pressure. (9.4.2)
- Depths and size of permeable formations with a flow potential in any wellbore shall be known. (9.6.1)

The illustration samples in “Norsok D-010 rev. 3 section; 9 Sidetracks, suspension and abandonment” are illustrating two different scenarios for temporary abandonment.

9.8.1 Temporary abandonment – Non-perforated well	Well barrier elements	See Table	Comments
	<b>Primary well barrier, last open hole</b>		
	1. Cement plug	24	Shoe track.
	2. Casing (liner) cement	22	
	3. Casing (reservoir liner)	2	Un-perforated w/2 each float valves.
	or		
	1. Cement plug	24	Shoe track.
	2. Casing cement	22	
	3. Reservoir casing	2	Un-perforated w/2 each float valves.
	<b>Secondary well barrier, temporary abandonment</b>		
	1. Casing	2	
	<b>Primary well barrier</b>		
	1. Casing (liner) cement	22	
	2. Casing (liner)	2	Liner above perforations.
	3. Liner top packer	43	
	4. Casing	2	Below production packer.
	5. Production packer	7	50 m below TOC in casing annulus.
	6. Completion string	25	
	7. Deep set tubing plug	6	
	or		
	1. Casing cement	22	
	<b>Secondary well barrier, reservoir</b>		
	1. Casing cement	22	Above production packer.
	2. Casing	2	Common WBE, between liner top packer and production packer.
	3. Wellhead	5	
	4. Tubing hanger	10	
	5. Tubing hanger plug	11	For SSWs.
	6. Completion string	25	Down to SCSSV.
	7. SCSSV	8	
	or		
	1. Casing cement	22	Intermediate casing.
	<b>Secondary well barrier, reservoir</b>		
	1. Casing cement	22	Intermediate casing.
	2. Casing	2	Intermediate casing.
	3. Wellhead	5	
	4. Tubing hanger	10	
	5. Tubing hanger plug	11	For SSWs.
	6. Completion string	25	Down to SCSSV.
	7. SCSSV	8	
	Note None		
	Note None		

## 4 OLF Guideline 117

Following the PSA Well Integrity Survey that was made in 2006, a Well Integrity Forum (WIF) was established as an initiative from OLF. The Well integrity Forum has subsequently issued a set of guidelines for well integrity recommending minimum content of information to be included in a Well barrier schematic (WBS).

Below is an extract from the guideline showing the recommendation in section 3.3:

OLF Recommended Guidelines for Well Integrity No.: 117 Date effective: 01.10.08 Revision no: 3  
Date revised: 29.11.10 Page: 13

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### 3. Guidelines of minimum data

The following minimum data have been agreed upon and act as a guideline:

1. The formation strength should be indicated for formation within the barrier envelopes.
2. Reservoir(s) should be shown on the drawing.
3. Each barrier element in both barrier envelopes should be presented in a table along with its initial integrity-verification test results.
4. Depths should be shown relatively correct according to each barrier element on the drawing.
5. All casing and cement, including the surface casing, should be on the drawing and labeled with its size.
6. There should be separate fields for the following well information: Installation, well name, well type, well status, rev. no and date, "Prepared by", "Verified/Approved by".
7. Include a Note field for important well integrity information.

## 5 Approach

The work has been undertaken to review whether the suspension or temporary abandonment has been done in a safe and prudent manner, focus has been on whether sufficient information to make such claim is available and the extent of documented qualification of the barrier elements.

What is the essence when we evaluate temporary or suspended wells?

(investigate – clarify – uncover – verify)

- Is it done in a safe manner with two barriers?
- Can barriers be monitored?
- Suitable for the duration?
  - Not addressed as there is not sufficient information about materials and monitoring method.

Authority prescription - What does the authorities demand

- Reduce probability of hazard
- Secure wells before they are to be abandoned
- Independent barriers
- Awareness to stakeholders of installed barriers and their purpose
- Monitoring or plugging of temporary abandoned wells

Norsok requirements – What is the industry prescribing as best practice

- Two barriers
- Installed as close to the inflow source as possible
- Plugs set at a depth when formation fracture pressure exceeds the potential internal pressure
- Tests to confirm long term integrity
- Verification of well barriers
- Consideration to mechanical barriers and casing degradation
- Identification of permeable zones

OLF guideline –What is the industry best practice for preparation of well barrier schematics

- Formation strength presented
- Reservoir shown
- Tabulated barrier listing with verification
- Correct relative depth representation
- Casing and cement shown
- Well and preparation data
- Notes

Other

- Does the Well barrier Schematic give a clear message to the reader
- Element strength
- Ability to re-enter?

The observations and findings to the reviewed individual well barrier schematics are presented in the appendix to the report.

## 6 Review method, findings and recommendations

### 6.1 Review method

When reviewing a well barrier diagram there are a number of parameters that need to be included in order to see whether this is a well configuration that has adequate and qualified barrier in place.

#### Requirements to barrier illustration demonstrating adequate barriers in place:

- Statement of the source pressure (at relevant permeable formations)
- Ability to see that primary and secondary barrier are in place internal and external to the tubular(s) and being independent of each other
- All main barrier elements shall be shown
- Identification of what is the weakest formation pressure in a hole section that can be exposed to reservoir pressure
- Adequate cement heights are available when used as a well barrier
- Adequate height between top reservoir and production casing shoe if cemented and used as a barrier
- Barrier elements (and cement in particular) qualification method
- Barrier monitoring method

#### Additional information that can be useful and add value

- Well type (producer, oil, gas, injector, observation)
- Maximum expected wellhead pressure
- Operating wellhead pressures, flowing and/or injecting
- Well status
- Notes and warnings
- Verified by a second party/person

### 6.2 Findings

In the review of the Well barrier schematics we have identified some points that are generally applicable to most of the illustrations, although there are some exceptions:

- There is seldom a description on the illustration to as why the well is abandoned, nor what the future plan is.
- With the exception of one, there is no reservoir pressure included on the illustration. This makes it **impossible** to assess whether the performed pressure tests and formation strengths are adequate as barrier qualification.
- There are examples of references made to shallow permeable formations that are not illustrated on the drawing. Such zones are not shown on the illustrations. There is a possibility that this is a general weakness in today's practice of showing well barrier illustrations.
- Most of the barrier illustrations do not have indication of being verified.
- Generally the WBS should include a suspension date and future plan stated in the Notes field.
- For a number of the wells there is no information of the actual age of the well. From some examples we can see that the wells can be up to 40 years old.



- With exception of one operator, no operator is using the well classification code on the illustrations.
- With the exception of one well, there are no information available as to how the barrier elements are to be monitored.

### **6.3 Recommendation**

Following the review of the provided well barrier schematics, the following recommendations are made:

- Reservoir pressure should be included in the well barrier diagrams.
- Formation strength should be quoted in pressure units rather than s.g. (the reader then need to calculate for himself based on formation depth).
- If preceding casing shoe cannot withstand a leaking pressure behind the casing, one should not illustrate the casing as a primary barrier and then as a secondary barrier at a point higher up. This cement column should be shown as a common barrier element and a risk assessment with mitigating measure should be summarized. In this case, a documented bond log with confirmation of good bond lengths should be considered.
- Compliance with OLF guideline 117 section 3.3 should be enforced. None of the presented illustrations are in full compliance (note that some of these illustrations are made before the OLF guideline was effectuated).
- For suspended and temporary abandoned wells there should always be presented a listing of how the barrier elements are monitored during the suspension/abandonment period.
- The following information would improve the functionality of the well barrier schematic:
  - Type of well
  - Date of suspension/abandonment
  - Reason for suspension/abandonment
  - Expected duration of suspension/abandonment
  - Date of preparation of the Well Barrier Schematic
  - Well status classification code
  - Well pressures (current surface shut-in/maximum expected tubing pressure)