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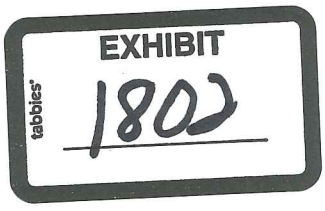
GP 10-60

Zonal Isolation Requirements during Drilling Operations and Well Abandonment and Suspension

Group Practice

BP GROUP
ENGINEERING TECHNICAL PRACTICES



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Introduction

The introduction to this ETP mirrors section 26 of the revised DWOP.

All zonal isolation activity shall conform to Engineering Technical Practice GP 10-60 – Zonal Isolation and Abandonment During Drilling Operations.

1. Zonal Isolation

Minimum requirement for Zonal Isolation

1.1 During Well Construction Zonal Isolation shall be designed to prevent:

- The development of Sustained Casing Pressure (SCP) during well operations.
- Prevent contamination of any aquifers.
- Prevent communication between any distinct permeable zones.

Materials

1.2 Material selection should consider well service (and any likely changes) and the impact of well conditions on zonal isolation for the life of the well. If an alternative material (to cement) is used an evaluation should be conducted to ensure it meets criteria required to provide isolation until permanent abandonment.

Design Criteria

1.3 Zonal Isolation design criteria for cementing of primary casing strings to meet well integrity and future abandonment requirements, shall meet one of the following:

- 30 mTVD (100 ft TVD) above the top of the distinct permeable zone where the top of cement (TOC) is to be determined by a proven cement evaluation technique (Section 5.3).
- 300 m MD (1000 ft MD) above the distinct permeable zone where the hydraulic isolation is not proven except by estimates of TOC (Section 5.3)

For each well the actual TOC shall be recorded along with the method used for this determination. Where the actual TOC is below the plan, the TOC shall be reviewed with stakeholders for its impact on future well integrity, operability, suspension and abandonment operations.

2 Suspension and Temporary Abandonment

Suspension and temporary abandonment shall be designed to ensure zonal isolation for the duration of the suspension and permit safe re-entry of the well.

Number of Barriers

2.1 Two temporary barriers are required for isolation of moveable hydrocarbon bearing or overpresssured permeable sections from surface/seabed.

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Verification of Barriers

2.2 The first barrier shall be pressure and / or inflow tested and tagged (if plug is set in openhole (OH) tagging only required), the second barrier shall be tagged or pressure tested.

3 Permanent Abandonment

The decision to permanently abandon or temporarily suspend a well shall be approved by the relevant Performance Unit Leader or their delegate and by the regulatory authorities.

Permanent abandonment shall be designed to protect aquifers, ensure isolation between distinct permeable zones and to prevent flow from them to surface or seabed.

- For hydrocarbon bearing permeable zones two permanent barriers are required from surface or seabed

For water bearing permeable zones one permanent barrier required from surface or seabed

Acceptable Barriers

3.1 Cement shall be the material acceptable for permanent abandonment.

Selection and location of permanent barriers

3.2 Good cement verified to be 30 m TVD (100ft TVD) above a distinct permeable zone shall be considered an acceptable permanent barrier.

To constitute a permanent barrier the annular cement around the plug setting depth should meet annular isolation requirements positioned to provide full lateral coverage of the well. Cement plugs shall be set at a point where formation strength is capable of controlling the pressure from the formations it is isolating.

Barrier Verification

3.3 Barriers can be verified by weight testing and/or pressure testing (positive and/or inflow). All primary barriers should be weight tested and pressure tested except:

- In OH where only weight testing is permitted (OH cement plugs cannot be accepted as the only barrier)
- When the plug has been set on a permanent mechanical barrier (when pressure testing is only required).

Weight testing should be up to at least 15K lb (6.8 Tonne). Pressure testing shall be 0.1psi/ft (2.26 KPa/m) above the leak off test (LOT) (or predicted fracture gradient at the shoe) or 500 psi (3.45 MPa) whichever is the greater. The pressure test is acceptable where pressure drop is <10% over 15 mins.

4 Special Considerations

Permafrost Cementing

4.1 The plugging material shall develop the required properties before freezing and not impact permafrost during setting.

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Aquifers

4.2 Fresh water aquifer should have annulus barriers extending a minimum of 30 m (100ft) TVD beneath the base of permeable interval containing the fresh water and 30 m (100ft) TVD above the top of the permeable fresh water interval or to surface. Plugs set inside pipe should extend 30m (100ft)TVD above the aquifer and provide a seal extending laterally across the entire well.

Control Lines

4.3 An abandonment cement plug with open control line through it shall not be accepted as a permanent barrier

Corrosive Environments

4.4 The potential for casing corrosion shall be accounted in the plugging plan

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Foreword

This is the first issue of Engineering Technical Practice (ETP) BP GP 10-60 dealing with Zonal Isolation and Well Abandonment and Suspension. This Group Practice (GP) replaces the relevant parts of the Drilling and Well Operations Policy BPA-D-01.

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1. Scope

This Group Practice details the minimum requirement for isolation of formation with flow potential during well construction and abandonment. It does not provide guidance associated with decommissioning of surface/sub sea facilities or barriers required during rigless operations. The broader issues of decommissioning are covered in the Exploration and Production Decommissioning Guidelines issued in 2006. For more detail on estimating plug and abandonment provision see Well Cost Estimating Handbook (ETP D&C 2006).

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. A list of the relevant API/ISO documents is included at the end of the GP which provides details on the industry recommended practices and standards for well cementing.

Norsok Standard D-010 Well Integrity in Drilling Operations

UKOOA Guidelines for the Suspension & Abandonment of Wells

MMS Code of Federal Regulations (CFR) Section 30 Part 250

3. Terms and definitions

For the purposes of this GP, the following terms and definitions apply:

Well

A well includes the original wellbore, any sidetrack from it and any hole section.

Permanent abandonment

The action taken to ensure permanent isolation from surface and prevention of inter zonal communication with the well for any well which will not be re-entered.

Suspension / temporary abandonment

The action taken prior to coming off the well to prevent flow to surface or inter zonal communication occurring for a well which will be re-entered

Permanent barrier

A verifiable barrier that will maintain a seal to prevent any leakage from the well after abandonment

Temporary barrier

A verifiable barrier that will maintain a seal for a finite time (longer than any planned suspension)

Permeable zone

Any zone in the well where flow is possible on the application of a pressure differential

Distinct permeable zone

A group of permeable zones which were originally in the same pressure regime and where flow between zones can be shown to be acceptable

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Sustained casing pressure

Sustained Casing Pressure is a pressure between tubing and/or casing strings that rebuilds after being bled down when the well is in static state conditions.

It is distinct and unrelated to pressure that may develop due to thermal changes in the wellbore.

4. Symbols and abbreviations

For the purpose of this GP, the following symbols and abbreviations apply:

API RP	American Petroleum Institute Recommended Practice
TOC	Top of Cement
SCP	Sustained Casing Pressure
APB	Annular Pressure Build up
CRI	Cuttings Reinjection
LOT	Leak off Test
HSSE	Heath Safety Security and Environment
OH	Open Hole
ZI	Zonal Isolatioon

5. Zonal isolation

5.1. Minimum requirement for zonal isolation

Zonal Isolation prevents flow of fluids to surface or between distinct permeable zones, it provides integrity to operate the well safely and permit safe abandonment of the well at a future date.

5.1.1. Defining zonal isolation

a. During Well Construction Zonal Isolation should be designed to prevent:

1. The development of SCP during well operations due to communication with a distinct permeable zone
2. Prevent contamination of any aquifers
3. Prevent communication between any distinct permeable zones.

For future reservoir management purposes it may be necessary to ensure isolation of different fluids within distinct permeable zones

5.1.2. Materials

A range of materials can be used to provide zonal isolation during well construction, selection should consider well service (and any likely changes) and the impact of well conditions on zonal isolation for the life of the well. If an alternative material (to cement) is used, an evaluation should be conducted to ensure it meets criteria required to provide isolation until permanent abandonment and its impact on future abandonment costs.

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Materials acceptable for providing zonal isolation during well construction are:

- *cement*
- *elastomers*
- *sand*
- *barite plugs*
- *slags and pozzolanic materials (with hydraulic capacity)*
- *resins*

5.1.3. Zonal isolation design criteria for primary casing strings to meet well integrity and future abandonment requirements

Cement design shall meet one of the following:

a. 30 mTVD (100 ft TVD) above the top of the distinct permeable zone where the TOC is to be determined by a proven cement evaluation technique (Section 5.3)

b. 300 m mD (1000 ft MD) above the distinct permeable zone where the hydraulic isolation is not proven except by estimates of TOC (Section 5.3)

For each well the actual TOC shall be recorded along with the method used for this determination. Where the actual TOC is below the plan, the TOC shall be reviewed with stakeholders for its impact on future well integrity, operability, suspension and abandonment operations.

In the event the cement isolation is not to be assessed by proven cement evaluation technique plan for at least 30 m (100 ft) of centralised pipe above the distinct permeable zone

5.2. Special considerations

5.2.1. Subsea wells

For sub sea wells APB considerations may require TOC to be designed short of the previous casing string, in this case TOC should be designed to isolate overpressured and/or hydrocarbon permeable zone and should not be closer than 500 m MD (1600 ft) to previous shoe to minimise risk of cement channelling and barite settlement plugging the annulus. Where these requirements are in conflict zonal isolation should take precedence.

5.2.2. Sidetracking capability and CRI

For low cost sidetracking capability or CRI, TOC maybe required below a casing shoe, isolation of any distinct permeable zone should be designed to meet requirements in 5.1.3. For a CRI well the tail cement should have the greater of 300 m md/ 50 mTVD (1000ft md/160 ft TVD) above the previous casing shoe to mitigate impact of facture height of CRI zone.

To minimise risk of annulus plugging due to cement channelling plan TOC >500 m (1600 ft) beneath the previous shoe but precedence is to isolate distinct permeable zones.

5.2.3. Kick off plugs

Where a kick off plug has been set a plug of sufficient length should be set to leave enough cement below the kick off point to comply with 5.1 for plugging of the old wellbore

Where cementing subsequent casing string can achieve compliance with 5.1 the length of plug beneath the kick off point is not critical.

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5.2.4. Expandables

Where an expandable is deployed the TOC should be considered in relation to its impact on future abandonment operations.

It is difficult to achieve zonal isolation using expandables and current practice is to not bring cement to the top of the liner. For development wells plan to isolate the expandable with the next primary cementing operation to eliminate any impact on future suspension and abandonment.

5.3. Determining zonal isolation

5.3.1. Cement evaluation logs

To accurately assess TOC and zonal isolation cement sonic and ultrasonic logs should be used.

To get accurate information from the logs they have to be run under optimum conditions (impacts of microannuli and gas can compromise log quality) and may need specialist log evaluation and / or interpretation

5.3.2. Cement column backpressure

The simplest way of estimating TOC is to determine the cement column hydrostatic by slowing the pumps down immediately prior to bumping the plug

This will only give a very coarse estimate and where cement and mud weights are very similar (within 0.2 SG) is unlikely to provide a sufficiently accurate estimate.

5.3.3. Temperature logs

Temperature logs can give a simple estimate of the TOC when they are run soon after cementing.

They identify a temperature anomaly usually associated with the heat evolved when the cement sets but give no indication of isolation.

6. Suspension and temporary abandonment

Suspension and temporary abandonment shall be designed to ensure zonal isolation for the duration of the suspension and permit safe re-entry of the well.

6.1. Principles of suspension

6.1.1. Number of barriers

Two temporary barriers shall be installed for isolation of moveable hydrocarbon bearing or overpresssured permeable sections from surface/seabed.

A single barrier is acceptable for normally pressured water bearing formations.

6.1.2. Well re-entry considerations

The method of suspension and barriers used shall enable the well to be re-entered safely and secured using pressure control equipment without compromising the barriers in place.

6.2. Acceptable barriers

As an alternative to cement, mechanical barriers may be considered for suspension. In this event the impact of anticipated length of the suspension / subsurface environment and type of well on the durability of the selected barrier should be made. If a full fluid column can be monitored and maintained it may be considered as a temporary barrier based on risk assessment.

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Pressure tested casing (positive or negative) is acceptable as a temporary barrier however in the event that pressure control equipment is to be removed annular barriers should be reviewed and risk assessed based on well condition and duration of suspension.

Issues to consider are fluids in the wellbore and potential impact on elastomers and any corrosive materials impacting metallurgy of barriers.

6.3. Verification of barriers

The first barrier shall be pressure and / or inflow tested and tagged (if plug is set in openhole taggng only required), the second barrier shall be tagged or pressure tested.

7. Permanent abandonment

The decision to permanently abandon or temporarily suspend a well shall be approved by the relevant Performance Unit Leader or their delegate and by the regulatory authorities.

Permanent abandonment shall ensure isolation between distinct permeable zones and to prevent flow from them to surface or seabed. It shall also protect aquifers containing potable water.

- For hydrocarbon bearing permeable zones two permanent barriers are required from surface or seabed
- For water bearing permeable zones one permanent barrier required from surface or seabed

7.1. Acceptable barriers

Cement shall be the material acceptable for permanent abandonment; it can be used in combination with other dry blended additives that do not damage its mechanical properties of low permeability and compressive strength.

Where an alternative material is being proposed for permanent abandonment, testing shall be completed to confirm it meets criteria of:

a) Low permeability (< 1 mD)

b) Long term mechanical stability. The mechanical properties of the material shall not be degraded by time / downhole conditions (including pressure /temperature and chemistry of fluids) it is exposed to.

c) Strength and/or ductility to accommodate mechanical loads or formation movements

d) Provide a permanent seal at the formation and casing interface

7.2. Minimum requirements for permanent barriers

Good cement verified to be 30 m TVD (100ft TVD) above a distinct permeable zone shall be considered an acceptable permanent barrier (see Section 7.4 for verification requirements).

Where possible it is recommended to place 150 m (500ft) or 30 mTVD(100 ft TVD) (whichever is larger) of cement to provide redundancy and mitigate contamination effects during placement.

In some cases it may not be possible to meet all the verification requirements detailed in 7.4 (e.g. where wells abandoned with completion in place), in these cases a minimum of 300 m MD (1000 ft MD) of cement should be placed above the distinct permeable zone to provide lateral coverage across the well at a depth where formation strength complies with requirements in 7.3. This type of plug shall meet pressure testing requirements detailed in 7.4.

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7.3. Selection and location of permanent barriers

Each distinct permeable section shall be isolated with a permanent barrier. In the event that there are multiple distinct permeable zones in the same section it is acceptable to set a single continuous cement plug across all the zones.

To constitute a permanent barrier the annuli around the plug setting depth should have good cement (defined in section 5) positioned opposite the planned plug to provide full lateral coverage of the well. Cement plugs shall be set at a point where formation strength is capable of controlling the pressure from the formations it is isolating and providing lateral well coverage.

Where a second barrier is required, it should be set so as to provide a backup to the uppermost primary barrier.

Where a second barrier is required its design and location should be appropriate to withstand any pressure that could develop in the event the first barrier fails.

A final cement plug should be set on surface for land locations, seabed clearance requirement are defined in Exploration and Production Decommissioning Guidelines

7.3.1. Plugs in open hole

A verified open hole cement plug across a distinct permeable zone is an accepted primary barrier (see 7.4 for verification requirements).

7.3.2. Plugs across casing shoes

A cement plug across the casing shoe can constitute the primary barrier where a distinct permeable zone in open hole will not impact future reservoir management and the fracture pressure at the shoe exceeds the formation pressure in the permeable zone.

In some cases cement can be set on a bridge plug set inside the previous casing shoe; this can eliminate the requirement for tagging the plug.

7.3.3. Plugs across perforations

Cement should be squeezed to perforations in gas wells.

Establishing a squeeze pressure against the perforations will be the best way of preventing fluids migrating through the cement while setting. Where there is no risk of fluid migration through cement while setting, it can be set above the production packer with completion in place assuming fracture gradient at this depth is greater than current or any future value for reservoir pressure.

7.4. Verification

7.4.1. Wellbore barriers

Barriers can be verified by weight testing and/or pressure testing (positive and/or inflow). All primary barriers should be weight tested and pressure tested except:

1. In OH where only weight testing is permitted.
2. When the plug has been set on a permanent mechanical barrier

Weight testing should be up to at least 15K lb (6.8 Tonne). Pressure testing shall be 0.1psi/ft (2.26 KPa/m) above the LOT (or predicted fracture gradient at the shoe) or 500 psi (3.45 MPa) whichever is the greater. The pressure test is acceptable where pressure drop is < 10% over 15 mins.

A pressure test can be replaced by an inflow test which provides the maximum differential the plug would see after permanent abandonment.

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Openhole cement plugs can not be accepted as the only barrier

7.4.2. Annulus barriers

See 5.1.3. for details for assessing if the annulus is isolated to meet abandonment requirements.

8. Special considerations

8.1. Remediation

Where annular isolation requirements have not been met during well construction they shall be achieved during abandonment.

Where there is evidence that zonal isolation has failed during well operations (development of SCP) remedial squeeze operations will be executed during well abandonment). Where zonal isolation has failed due to channelling during cement placement and or seal failure during well operations more complex squeeze operations or removal of an interval of cemented casing may be required.

8.2. Gas wells / shallow gas

When isolating formations containing gas; an assessment of the potential of gas migration through setting cement should be conducted. In these cases holding back pressure on the plug / squeeze and / or use of specialist designs should be considered.

Wells with shallow gas /water flow potential can refer to API RP 65 part 1 and 2 during primary construction to ensure adequate design procedures have been used.

8.3. Uncemented liners

If there are multiple distinct permeable sections behind uncemented pipe these should be isolated from each other.

Where the well has uncemented pipe covering a distinct permeable zone the recommended approach is to set cement on a mechanical barrier set above the distinct permeable zone . Where more than one distinct permeable zone is covered by an uncemented pipe it is recommended to provide isolation during well construction to reduce abandonment liabilities.

8.4. Corrosive environments

Where the materials used for permanent abandonment may be exposed to corrosive environments the materials chemical stability shall be confirmed

This can include CO_2, H_2S and some groundwater's that may impact the mechanical stability of the plugging material.

8.5. Permafrost cementing

Barrier requirement are the same for abandonment of artic wells, however for plugs across permafrost the cement design shall take account of the impact on the permafrost of the plugging material. The plugging material shall develop the required properties before freezing.

The heat evolved from any plugging material may damage the seal to the formation and it may be necessary to select specially designed plugs to prevent destabilisation of the permafrost.

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8.6. Multilateral wells

It may not be possible to obtain entry to one or more legs of a multilateral after completion and plugging of the junction to isolate individual well bores should be attempted where they are into separate distinct permeable zones.

Annulus isolation to each multilateral leg should be considered at the well construction phase.

8.7. Aquifers

Aquifers shall be isolated from contact with fluids moving from another distinct permeable zone after completion of the abandonment process. A fresh water aquifer should have annulus barriers extending a minimum of 30 m (100ft) TVD beneath the base of permeable interval containing the fresh water and 30 m (100ft) TVD above the top of the permeable fresh water interval or to surface. Plugs set inside pipe should extend 30m (100ft)TVD above the aquifer and provide a seal extending laterally across the entire well.

8.8. Control lines

An abandonment cement plug with open control line through it shall not be accepted as a permanent barrier.

Where control lines are to be installed during well construction consideration should be given to the ability to plug the control line during abandonment or installing a control line which does not provide a flow path. Alternatively the depth of the control line should be considered with respect to the abandonment requirements in Section 7

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A wide range of industry papers can assist with this process, the following standards and industry recommended practises.

Document No	Title	Synopsis
API RP 65 Part 1	Cementing Shallow Water Flow Zones in Deep water wells	Covers design processes for cementing where the risk of shallow water flows are high. Includes test procedures and checklist for design of cement slurries to prevent shallow water flow.
API RP 65 Part 2	Isolating Potential Flow Zones in Well Drilling and Cementing Operations	To be published in 2008 detailing considerations for cementing zones that may be a source of SCP.
API RP 90	Annular Casing Pressure Management for Offshore Wells	Complimentary document to API RP 65 describing diagnosis and management of SCP.
API 10TR1	Cement Sheath Evaluation	Provides the current principles and practices regarding the evaluation and repair of primary cementations. Cement bond logs, compensated logging tools and borehole compensated logging tools and ultrasonic logs.
ISO 10426-5	Recommended Practice on Determination of Shrinkage and Expansion	This standard provides the methods for the testing of well cement formulations to determine the dimension changes during the curing process (cement hydration) at atmospheric pressure only. This is a base document, because under real well cementing conditions shrinkage and expansion take place under pressure and different boundary conditions.
ISO 10427-1	Casing Centralisers Part 1 Bow Spring casing centralisers.	Provides minimum performance requirements test procedures and marking requirements for bow spring casing centralisers. Specification does not cover rigid centralisers.
ISO 10427-3	Equipment for well cementing – Part 3 Performance testing of cementing float equipment.	Describes the testing and practices to evaluate the performance of cementing float equipment.
ISO 10426-1/Amd 1	Cements and Material for well Cementing	Specifies requirements and gives recommendations for eight classes of well cement including their chemical and physical requirements and procedures for physical testing.
ISO 10426-2	Cement and Materials for well cementing Part2: Recommended practice for testing of well cement.	Provides guidance for the testing of cement slurries and related materials under simulated well conditions.
ISO 10426 – 3	Cements and materials for well cementing – Part 3: recommended practice for testing of deep-water well cements.	Covers design processes for cementing where the risk of shallow water flows are high. Includes test procedures and checklist for design of cement slurries to prevent shallow water flow.
ISO 10426 - 4	Cement and Materials for well cements – Part 4 Recommended practice for atmospheric foam cement preparation	Describes laboratory procedures for preparing and testing foam cement slurries.

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