WELL ABANDONMENT GUIDELINES

INSTITUTO BRASILEIRO DE PETRÓLEO E GÁS

2nd Edition – November, 2022

Foreword

This document was developed to assist in achieving compliance with the Plug & Abandonment regulatory requirements contained in the Technical Regulation of the Well Integrity Management System WIMS/SGIP and is aligned with international good practices established in documents such as NORSOK D-010 (2021) and the Oil & Gas UK – Well Decommissioning Guidelines (Issue 6, 2018).

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PRESENTATION

The Drilling & Wells Committee of the Instituto Brasileiro de Petróleo e Gás (IBP), hereinafter referred to as D&W, was established in 2013 to discuss and deal with relevant topics for its associates and the industry, as well as issues related to regulatory compliance and environmental requirements, in the scope of well activity.

As of the first semester of 2014, having a new regulatory framework being developed by the National Agency of Petroleum, Natural Gas and Biofuels (ANP), aiming to ensure safety and integrity of oil and gas (O&G) wells throughout their lifetime, the discussions held by the D&W committee prioritized this theme and established a collaborative approach with ANP, for contributions to build the new regulation. Consequently, D&W created 4 (four) Work Groups (WG), with the participation of 20 associated Operators, encompassing different action focuses of the new regulation. WG1 dealt with topics related to well design and construction; WG2 discussed items regarding the phases of well production, intervention and abandonment; WG3 focused on aspects regarding operational safety and emergency plans; while topics related to onshore wells were treated by WG4. The WGs began their work in the second semester of 2014 and concluded them in the first quarter of 2015. In the following months the results were discussed in a collaborative way with ANP, with the presentation of several proposals for the Agency´s final WIMS/SGIP text.

Resolution ANP nº 46/2016, published on November 3rd, 2016, established the Technical Regulations for the Well Integrity Management System (SGIP), with a minor rectification issued on November 7th of the same year. This Resolution established a 6-month period for adjustment by operators to the requirements for Well Abandonment (Management Practice 10.5), while for the remaining regulation requirements this period was established as 2 (two) years, subject to an extension of up to 3 (three) years in specific cases, having the possibility of a final request for an additional extension for the same duration, at most.

In view of the shorter period for adequation to the well abandonment requirements and considering SGIP´s predominantly non-prescriptive nature, a specific Work Group was established by D&W to elaborate a document containing guidelines and good practices related to the installation and verification of Well Barriers (WBs). These guidelines have the purpose to ensure compliance with SGIP requirements, as well as to establish a standardization with minimum criteria for active Operators in Brazil, covering not only typical scenarios of the Brazilian maritime environment for oil and gas extraction in deep and ultra deep waters, but also in shallow water environments as well as for onshore wells, covering the entire portfolio.

The first meeting of the so-called "Abandonment WG" took place in September 2016, with several weekly or bi-weekly meetings during six (6) months. This Work Group concluded its work in March 2017, when the first draft was issued, which was then reviewed internally by the participating Operators to verify possible points for improvement.

During the months of April and May 2017, the draft was also discussed with the ANP/SSM (Environment and Operational Safety Department) technical team, to capture the regulator's view, as well as comments and suggestions for adjustments to the document guidelines.

After approval of the document by IBP's D&W Committee, the first consolidated Guidelines version was completed in May 2017.

In 2018, with the expansion of technical scope related to well integrity throughout the lifecycle of O&G wells used for Exploration and Production (E&P) activities, the D&W had its name changed to Technical Operations Committee of IBP.

In April 2021, with the creation of a new Abandonment Work Group, a first meeting was held to present proposals to update the first edition of the Well Abandonment Guidelines, published in 2017, capturing the Operators' perceptions about evolution in the field and alignment with other industry publications. During the months of June and July, a draft containing the changes indicated by the operators was prepared.

From August to November 2021, the ANP/SSM technical team had access to the draft, allowing prior knowledge of the Operators´ understanding regarding the updates and improvements of the abandonment practices occurred from 2017 to 2021. In December 2021, a Workshop was held comprising the ANP/SSM technical team, the Abandonment Work Group and IBP's Technical Operations Committee, when regulator comments and suggestions were received and addressed.

With approval of the document by IBP's Technical Operations Committee, the second version of the Well Abandonment Guidelines was published in November 2022.

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DEFINITIONS, ACRONYMS AND ABBREVIATIONS

ALARP (As Low As Reasonably Practicable)	Is the concept that efforts to reduce risk must be continuously employed up to the point where additional sacrifice (in terms of cost, time, effort or other use of resources) is vastly disproportionate to the benefit of additional risk reduction
AMB	Annulus Mechanical Barrier
ANP	Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (National Agency of Petroleum, Natural Gas and Biofuels)
Aquifer	Permeable interval containing water of any nature, potentially destined for public or industrial utilization or when the interval is responsible or potentially responsible for driving the production of an oil or gas reservoir (see item 2.1.2)
BHA	Bottom Hole Assembly
BOP	Blowout Preventer
CAB	Completion Adapter Base
Cased well (Cased hole)	Well section covered by a casing
Cemented Shoe track	Casing interval between its shoe and floating collar filled with cement in the inside
CNEN	National Nuclear Energy Commission – *(Comissão Nacional de Energia Nuclear)*
Combined WB	Well Barrier having sufficient length to be considered as both Primary and Secondary WB for a given pertinent interval. It might be formed by element(s) from both WBs which were installed and verified in a single operation (example: cement plug, primary casing cement job; PWC; annulus cement remediation, etc.)
Combined WBE	Well Barrier Element installed and verified in a single operation which represents two elements in one, resulting in a Combined WB. Example: cement plug section or annulus cement (installed by methods such as primary casing cement job, cement remediation, PWC, etc.) having double the length in relation to that required to result in a single WB Element.
Creeping Formation	A formation with plastic extrusion into the well sealing the annulus between the formation and the casing or liner

CXT (or DXT)	Conventional X-Mas tree (or Dry X-Mas tree)
DFIT	Dynamic Formation Integrity Test
DHSV	Downhole Safety Valve
DIV	Downhole Isolation Valve
DPR	Drill Pipe Riser
DSV	Double Seal Valve
EAC	Barrier Element Acceptance Criteria
ECD	Equivalent Circulating Density
ECP	External Casing Packer
ESP	Electric Submersible Pump
FIT	Formation Integrity Test
FIV	Formation Isolation Valve
(Naturally) Flowing well	A well with sufficient reservoir pressure to lift formation fluids and maintain steady flow to the surface or seabed. For wells connected to the rig or SPU, naturally flowing condition must be verified both to the surface and the seabed
Good practices	Practices and reference procedures aiming at: a) Application of employed methods and procedures worldwide in O&G Exploration and Production activities; b) Conservation of petroleum resources, which implies the use of appropriate methods and processes to maximize the recovery of hydrocarbons in a technically, economically and environmentally sustainable manner, with the corresponding mitigation of the decline of reserves and minimization of surface losses; c) Operational safety, which requires the use of methods and processes that ensure the safety of operations, contributing to the prevention of incidents; d) Preservation of the environment and respect for populations, which determines the adoption of technologies and procedures associated with the prevention and mitigation of personnel and environment damage
GOR	Gas-Oil Ratio

HFIV	Hydraulic Formation Isolation Valve
HPHT	High Pressure and High Temperature
HXT	Horizontal X-Mas Tree
IBP	Instituto Brasileiro de Petróleo e Gás (Brazilian Institute of Oil & Gas)
Internal potential pressure	Maximum anticipated pressure due to formation fluids migration that could be developed below WBEs after permanent or temporary well abandonment. This pressure might be caused by secondary recovery methods and/or tertiary, i.e., water or gas injection, or due to formation repressurization
Interval with flow potential (IFP) or Source of Inflow	An interval containing fluids with migration capacity, current or future, between media with distinct pressure regimes and/or fluid nature (refer to Item 2.1.1)
Investigation well	Well which purpose is to identify the presence of shallow overpressured zones, drilled with seawater without drilling riser and fluid returns to the seabed
ISO	International Organization for Standardization
LOT	Leak Off Test
Non-flowing well	A well with insufficient reservoir pressure to lift formation fluids and maintain steady flow to the surface or seabed and maintain steady flow. For wells connected to the rig or SPU, flow condition must be verified both to the surface and seabed
Oil & Gas Reservoir	A permeable interval containing mobile gas or mobile oil with exploitation potential
Open hole	A section of the well without casing, including intervals with screens or/ perforated/slotted tubulars
PAB	Production Adapter Base
PBP	Permanent Bridge Plug
PDG	Permanent Downhole Gauge
Permanent abandonment	A situation of a well in which Permanent Well Barriers are installed and there is no intention (interest) in reentering into the well

Permanent WB	Assemble which aims to avoid unintentional flow, in the present and future, of formation fluids, considering all possible leak paths. The Permanent WB shall be positioned across an impermeable formation along a cross-sectional section, having a formation with sufficient strength in the base of the WB. Cement or other material with similar performance (plastic sealing formations included) shall be used as Well Barrier Elements
Pertinent Interval	Formation interval (formation) that requires isolation, whether Interval with Flow Potential or Aquifer
Primary WB	The first well barrier on top of the respective IFP or Aquifer, installed to control unintentional flow (primary well control). Once the requirements set in this Guidelines are met, the Primary WB for a formation might be the Secondary WB for another formation and vice-versa
PWC	Perforate, Wash, and Cement
RBP	Retrievable Bridge Plug
RCD Sealing Element	RCD element which seals inside the work string. The sealing element allows pressure to be applied to the well
ROV	Remotely Operated Vehicle
Sealing formation (caprock)	Any competent, impermeable formation, without flow potential
Secondary WB	The second well barrier on top of the respective IFP or Aquifer, installed to control unintentional flow (secondary well control)
SGIP (WIMS)	Sistema de Gerenciamento da Integridade de Poços (Well Integrity Management System)
Shared WBE	A Well Barrier Element simultaneously part of the primary and secondary well barriers for the same Pertinent Interval. Example: wellhead or X-Mas tree (in some temporary abandonment situations)
SPU	Stationary Production Unit

SSSD (Subsurface Safety Device)	Safety equipment installed below the land/seabed surface, with the ability to prevent uncontrolled flow of hydrocarbons to the external environment through the production or injection casing, enabling fail safe closure in case of catastrophic damage to aboveground equipment. Typical SSSDs are: Downhole Safety Valve (DHSV), Tubing-Retrievable Tubing Operating (TRTO) and BRV (Back Pressure Valve and Retainer Valve)
Temporary Abandonment	A situation of a well in which temporary Well Barriers are installed. Additionally, producer or injector wells already completed waiting for the restart of production (or already operating wells that for some reason are closed) are considered as temporarily abandoned
Temporary WB	Assemble of one or more barrier elements to form a safety envelope to avoid unintentional formation flow during a defined period, considering all possible paths
TOC	Top of Cement
Verified WBE	Well Barrier Element which performance was verified by evaluating post-installment or observations recorded during its installation and might be subject to periodic monitoring when required by this industry Booklet (refer to item 6)
WB (Well Barrier)	Assemble of one or more elements aiming to avoid unintentional flow from a zone/formation to the external environment and in-between zones, considering all possible leak paths
WD	Water Depth
Well	An interconnection structure between the surface (onshore or offshore) and the reservoir, built with the purpose to conduct fluids safely and efficiently, with capacity to withstand loads and stresses from aggressive agents during the well lifecycle. Stratigraphic wells are also included in this definition. A well includes the original borehole, any sidetrack from the original well or any shared well section
WXT	Wet X-Mas Tree

1 INTRODUCTION

The guidelines and good practices contained in this document are intended to serve as an aid for Operators associated to IBP, to develop (design) and execute oil and/or gas well abandonment projects, whether permanent or temporary.

This document provides a practical guide containing criteria and guidance to install Well Barriers (WBs) to achieve zonal isolation while meeting current regulatory requirements and industry good practices.

These guidelines aim to assist Operators to comply with well abandonment practices and procedures with respect to general requirements established in the Well Integrity Management System (WIMS), ANP Regulation Management Practice nº 10, in its item 10.5, which deals with requirements for well abandonment and zonal isolation. The WIMS is a regulation essentially focused on ensuring well integrity throughout their lifecycle and performance based, with a few prescriptions, and on operational risk management, adhering to the ALARP risk criteria. The ALARP concept can be understood as the application of efforts to reduce the risk until reasonable available conditions are exhausted (in terms of cost, time, effort or other employment of resources), such that the gain to be obtained, with its further reduction, does not justify the investment to control the risk in question. In other words, ALARP represents the acceptable risk limit, since operational activities in the petroleum industry have an intrinsic risk that cannot be reduced to zero.

These guidelines seek to establish, in a simple and didactic way, minimum criteria for the adequate isolation of the pertinent intervals in the abandonment of wells, standardizing the common understanding of these criteria and guiding good practices to be adopted by Operators in Brazil. It should be noted, however, that these guidelines are not intended to eliminate or override any criteria, standards and internal rules of each Operator, which may be adopted in a complementary or priority manner to the minimum criteria established in these guidelines, provided they do not incur in unacceptable risks.

It is understood that the application of the principles and practical guidelines contained in this document will lead to an effective and efficient isolation of the pertinent intervals and the establishment of a safe condition for the abandoned well, preventing unintentional flow of fluids between zones and to the external well environment (surface or seabed), ensuring the safety of people as well as the environment.

Despite all efforts to ensure the usefulness and comprehensiveness of these guidelines, IBP and the participant Operators in the Work Group assume no legal, regulatory, or technical responsibility for their use. Likewise, no liability is assumed regarding consequences arising from actions taken based on the recommendations expressed in these guidelines.

The E&P Good Practices Booklet – Well Abandonment Guidelines is subject to periodic reviews. Feed-backs, comments and consultations for clarifications can be forwarded by e-mail to: CBPabandono@ibp.org.br.

Additional note: the official/original document containing the Brazilian Well Abandonment Guidelines was published by IBP on November 2022 in Portuguese only. In case of conflict, the original (Portuguese) version shall always prevail over this English translated version.

2 GENERAL GUIDELINES FOR WELL ABANDONMENT

Well abandonment is part of the scope of well construction and intervention activities aiming to ensure well integrity. Implementation of abandonment configurations must comply with the requirements and principles from ANP Resolution nº. 46, of November 3rd, 2016, which established the WIMS.

Well abandonment requires the establishment of Well Barriers (WBs) to ensure the isolation of aquifers and intervals with flow potential, preventing unacceptable fluid flow caused by:

i. Unintentional fluid migration between permeable formations, either through the interior of the well or through its annular spaces;

ii. Migration of fluids from the formation to the surface or to the seabed.

Well abandonment involves the following activities:

a) Temporary well abandonment, characterized by a set of operations conducted in a well in order to ensure isolation of its pertinent intervals, involving the perspective (expectation) of future well reentry;

b) Permanent well abandonment, characterized by a set of operations conducted in a well in order to ensure permanent isolation of its pertinent intervals, and there is no interest of future well reentry.

Aiming at operational and human safety, environmental protection, and compliance with legal requirements, it is up to the well Operator to design and install WB Elements in the well to isolate intervals with flow potential, whether current or future, or aquifers. The responsibility of the Operator during the selection of the design and execution of the WB Elements includes the choice of the abandonment type/method, and communication with the regulator will be done through the Notification of Well Barriers and, when applicable, the Final Well Abandonment Report, which must be forwarded in accordance with the deadlines established in ANP Resolutions 46/2016 and 699/2017, or any regulation that may supersede them.

For the abandonment of wells containing pertinent intervals, the following WBs shall be established:

a) At least 2 (two) WBs, whether separated or combined, to prevent unintentional flow of fluids to the external environment;

b) At least 1 (one) WB to prevent flow of fluids between intervals not naturally connected, when such flow is deemed unacceptable.

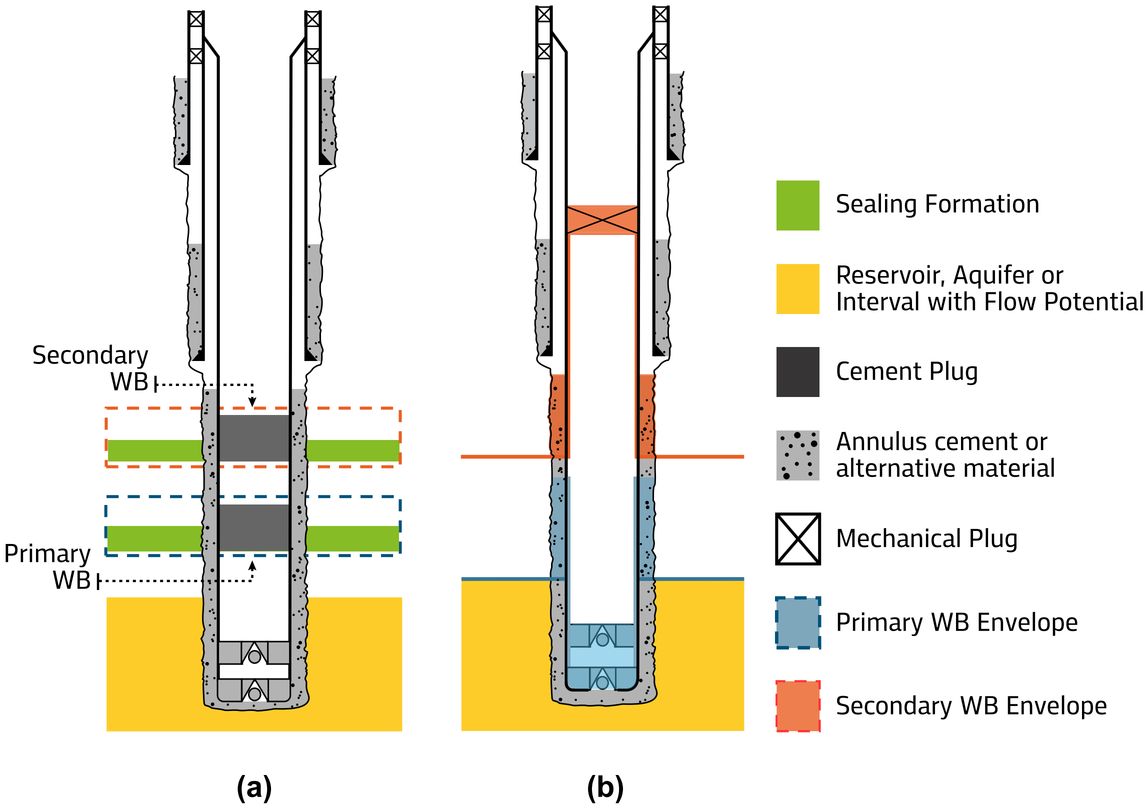
If the well had not achieved any pertinent interval, for the abandonment it shall be stablished, as a minimum, 1 (one) WB to prevent any eventual unintentional flow of fluids to the external environment.

Note: In an offshore well, this WB can be dismissed if the well has not progressed beyond the first drilled section.

WBs must be installed and verified in compliance with their respective procedures and acceptance criteria, as well as aligned with the industry good practices (see item 6).

For each abandoned well, it shall be prepared a schematic showing the WBs and its WBEs.

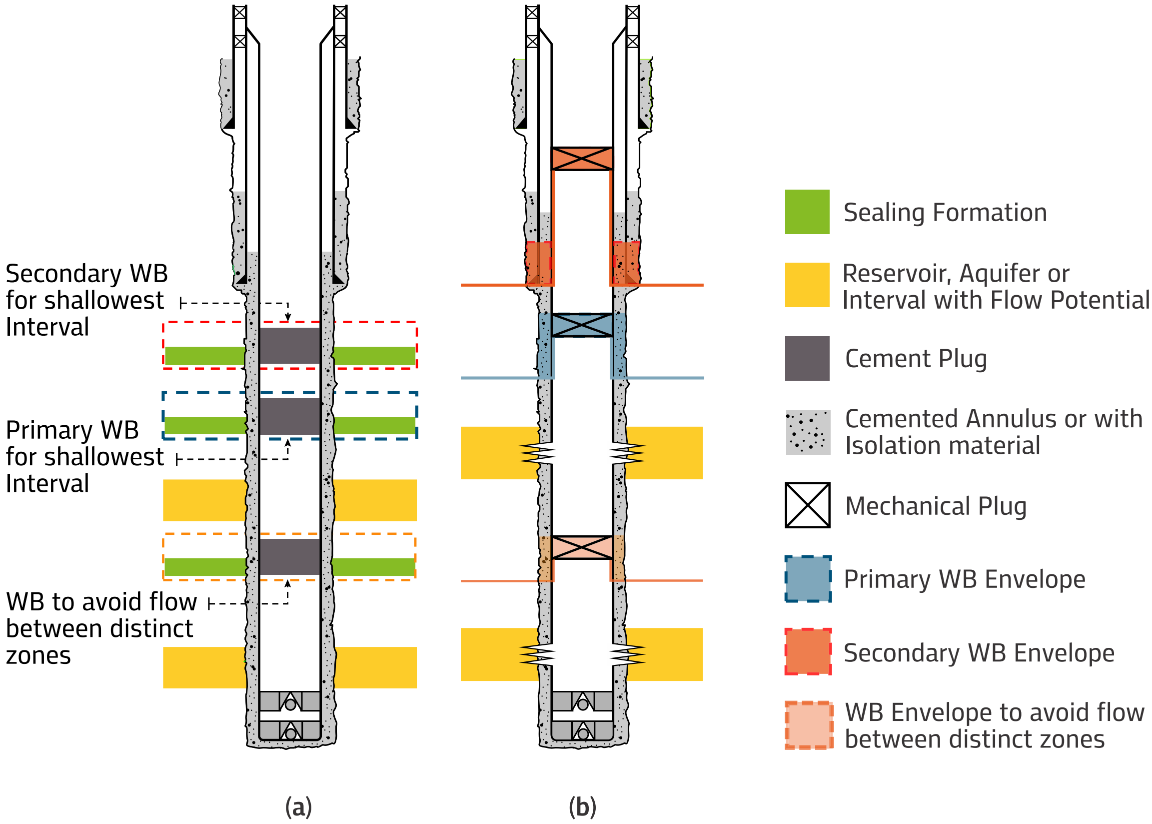
Figure 1 – Examples of abandonment with: (a) 2 Permanent WBs; (b) 2 Temporary WBs



Source: Prepared by the Authors.

Intervals with flow potential connected due to drilling shall be isolated in-between them by establishing one (1) WB to prevent unacceptable flow of fluids between naturally unconnected intervals, either in open or cased hole.

Figure 2 – Examples of isolation between zones: (a) permanent abandonment; (b) temporary abandonment



Source: Prepared by the Authors.

Distinct zones do not need to be isolated from each other if already naturally connected somewhere in the field, and not only by the drilling activity itself.

2.1 Identification of intervals with flow potential, aquifers and required isolations

To define which sections of a well shall be isolated during its abandonment, it is firstly necessary to identify the intervals with flow potential and/or aquifers crossed during drilling operations. Once these intervals of interest are identified, the need to establish a Well Barrier (WB) must be analyzed to prevent the occurrence of unacceptable flow between different media that would occur should these barriers were not installed.

2.1.1 Zones with flow potential

Zones with flow potential are those rock intervals crossed during drilling which contain fluids with migration potential, in the present or in the future, from their interior to another rock medium capable of receiving them or, alternatively, to the external environment. Thus, it is necessary that they have, at least:

i. Storage capacity for fluids;

ii. Fluid with capacity to flow inside the media;

iii. Fluid with enough differential potential to be transported to another medium.

Consequently, to meet these requirements, there must be:

i. Porosity and lateral extension of the rock;
ii. Transmissibility of rock matrix and/or fractures;
iii. Sufficient pressure and/or density differential to displace the fluid to its destination.

The above-mentioned conditions are related, exclusively, with the potential of flow of an interval, meaning that these are primary requirements to be met for a flow to become possible. However, the actual occurrence of flow depends, besides these factors, on the existence of a hydraulic communication between the media, where the well would serve as a conduit for the flow of the fluid. Thus, the magnitude and sustainability of the flow starting at a certain interval - that is, its flow over time - is a function not only of rock and fluid parameters, but also of any mechanical conditions to be observed in the well, along the fluid flow path.

To evaluate and classify the intervals it is necessary, firstly, to gather inputs acquired in previous stages of the well life cycle. Below are examples of key information recommended to be collected:

i. Seismic data mapping:
    a. Mapping the geometry of the intervals;
    b. Verification of continuity, length, and communication between intervals;
    c. Mapping of the geological structures that communicate/isolate the intervals.
ii. Well construction data:
    a. Drilling events report (indication/occurrence of kick or loss);
    b. Well Schematic;
    c. Geological information;
    d. Well logs;
    e. Rock samples.
iii. Geological description:
    a. Stratigraphic identification;
    b. Identification of permo-porous intervals;
    c. Identification of saturating fluid;
    d. Identification of overpressured intervals;
    e. Positioning, structure and competence of sealing formations (caprocks)

2.1.2 Aquifers

With the objective of analyzing the required isolations for a well, all rocky intervals containing water capable of serving one of the following purposes shall be classified as aquifers:

i. Be object of public or industrial use, as long as it contains water with properties for human consumption, whether for personal use or for productive processes (such as agriculture or factories), or for animal consumption. These aquifers may be at the surface or underground, and may include natural replenishing and discharging zones or be confined;

ii. Be responsible for the production mechanism of an oil or gas reservoir, provided that the water has or may have a relevant role in the process of sustaining the reservoir pressure, which requires that the aquifer be naturally communicated to an accumulation of hydrocarbons with commercial exploitation viability and that it contributes or may come to contribute in a noticeable way to its recovery.

For this aim, it is necessary, that the interval has the capacity to store and allow water flow, i.e., it must present permoporosity and sufficient lateral extension.

To evaluate whether intervals must be considered aquifers, it is recommended to collect information from:

i. Well logs;

ii. Occurrences observed during drilling operations;

iii. Analysis of the physicochemical qualities of the water;

iv. Interpretation of geological models of the region.

2.2 Analysis of required isolations

Based on the intervals with flow potential and aquifers identified in a well, it is possible to define the sections of the well that require the installation of barriers. The sections to be analyzed are those between different intervals of interest or between these intervals and the external environment (land or sea floor). In general, the objectives of these isolations are to:

i. Avoid sustained escape of hazardous fluids to the external environment (preservation of the environment and people´s safety);

ii. Avoid compromising water sources for human or industrial consumption (public interest);

iii. Avoid unacceptable damage to economically viable reservoirs;

iv. Avoid the reactivation of a geological fault that can lead to the direct or indirect occurrence of any of the previous situations.

For the purpose of identifying the need for isolation, one must consider:

i. The objective(s) that would be met by the respective isolation;

ii. The condition of isolation between formations - existing or not - during previous stages of the well life cycle.

Furthermore, the capacity for fluid migration between the media treated in the previous items must exist without assistance from artificial lifting mechanisms. On the other hand, the analysis of the necessary isolations must include possible migration capabilities that might become possible by circumstances related to other wells, such as water or steam injection used in advanced hydrocarbon recovery or by natural reservoir pressure recharge over time in the surroundings.

If a need for isolation is identified, the quantities of WBs indicated in item 2 must be adopted, depending on their function.

In case it is decided to not isolate between different pertinent intervals, the sealing formation (caprock) above the uppermost interval shall have sufficient strength to enable the positioning of the WB to isolate these intervals from the external environment.

Cases where the operator concludes that the regulation (SGIP - WIMS) requires certain isolation(s) or a certain type of barrier which – in its technical evaluation from the perspective of the industry good practices – could be dismissed, must be previously agreed upon with the regulator.

2.2.1 Admissibility of flow and barrier characteristics

The communication between different intervals with flow potential or between intervals with flow potential and production mechanism aquifers is something often desired for the exploitation strategy of a field, which can promote an increase in the recovery factor of reservoirs and make the economic exploitation of smaller accumulations feasible. The communication between intervals in such situations is a commonly adopted practice in the development of several oil reservoirs in Brazil and worldwide.

The considerations about which strategies to adopt for the best management of intervals during the production stage – whether to leave them communicated or not – are not object of this Good Practices Booklet, and should be subject of specific analysis by each Operator, for their respective O&G fields, based on their technical knowledge and learned experience.

For the purpose of this Good Practices Booklet, the admissibility of flow for the abandonment period must be decided based on the events that need to be avoided, thus, a potential flow of fluids that leads to the non-fulfillment of any of the objectives mentioned above must be considered unacceptable.

In general, the barriers that would provide the necessary isolations can be of a temporary or permanent type, depending on the stage of the well's life cycle and the objectives they are intended to fulfill.

During the productive life of a well, prior to its permanent abandonment, all WBs can be of temporary nature. For the permanent abandonment of the well, as a rule, the WBs must only be of permanent nature. However, depending on the objective to be met by the WBs, such as, for instance, the isolation between different intervals, in order to preserve the economic value of hydrocarbon reservoirs, the use of a temporary barrier may be allowed, provided there is no need to maintain this isolation for an undetermined period of time. In this case, isolation during the period of exploitation of the deposits, by means of temporary barriers, might be sufficient.

2.3 Abandonment project (design)

The abandonment project (design) must be prepared with the intention of composing permanent or temporary WBs in order to provide isolation. To facilitate the identification of the WBs in the abandonment project, the well schematic should highlight the envelope interconnecting the elements and composing the WBs, and the verification method for each WB element must be defined.

The following information must be considered while preparing the abandonment project (design):

i) Well life cycle history;

ii) Well configuration, including geometry (architecture), trajectory (deviation), depths and pertinent intervals' specifications; casings, cement condition behind the casings, open hole sections and existing sidetracks;

iii) Stratigraphic sequence of the well exhibiting intervals with flow potential and information on fluid types and reservoir pressures for the entire abandonment period;

iv) Logs, data and information from primary and secondary cementing operations, when applicable;

v) Identification of sealing formations (caprocks) with suitable properties to compose an WB element throughout the formation path (strength, impermeability);

vi) Specific well conditions such as presence of scale, sand, casing collapse, tubing rupture, fish, injectivity, pore pressure, presence of H_2S, presence of CO_2, presence of hydrates, corrosion or other special situations;

vii) Equipment installed and interconnections with the Stationary Production Unit (SPU).

Changes related to the abandonment project that may occur during its life cycle must be considered in its review as part of the project management and the management of change process, when applicable. The potential impacts caused by configuration changes should be considered in the criticality assessment of the future abandonment project, for instance through the performance of a risk analysis.

2.3.1 Temporary abandonment project

The temporary abandonment project features the composition of WBs throughout the well, by interconnecting WB elements, and often involves the installation of mechanical elements in the well for this purpose. Cemented casing annulus verified above the pertinent intervals prevent fluid migration through the annulus, and the metal tubulars verified prevent communication between the interior of the well and its annulus, ensuring non-communication for the estimated maximum pressure levels in the well for the abandonment period. In some situations, it may involve the installation of cement plugs or alternative materials as an interconnecting element, or even the use of WBs adhering to permanent abandonment guidelines.

2.3.2 Permanent abandonment project

The permanent abandonment project features the composition of WBs in a given well section restoring the pre-existing natural isolation provided by the sealing formation (caprock) before the well was drilled. This isolation is achieved by physically interconnecting the WBs elements from the inside of the smallest diameter tubing present in the selected section until reaching the sealing formation (caprock) and typically involves the presence of cement or alternative materials as WB elements present in all casing annuli in the well. The outermost cemented annulus can be replaced by a creeping formation if this is confirmed as acting as a barrier element.

3 TEMPORARY WELL ABANDONMENT

During a well´s life cycle, it may be temporarily abandoned for several reasons, including technical, operational and safety motivations.

In temporary well abandonment, consideration should be given to the conditions to which the WB elements will be exposed during the anticipated abandonment period, to allow a safe reentry in the future to resume well activities.

Depending on the specific conditions, such as well environment and exposure to physical or chemical effects, it is recommended that the Operator must consider the protection/preservation of the wellhead for future reentry.

Wells in the temporary abandonment status shall have a periodic visual inspection program, according to the E&P Good Practices Book – Guidelines for Monitoring Wells in Temporary Abandonment.

For temporary abandonment, it is recommended to install a permanent WB adherent to the technical guidelines of this Book (see item 4) when:

- There is uncertainty regarding expectation or interest in a future reentry;
- There is no capacity, viability or interest in the execution of a periodic monitoring program.

If, posteriorly, the operator decides that there is no interest in future reentry, it must proceed with the processing, with the regulator, of the document(s) required in the WIMS' Technical Regulation, or regulation that may supersede it.

3.1 Emergency disconnection and operational disconnection

In some situations, it may be necessary to interrupt well operations, in the construction or intervention stages, which does not characterize a temporary abandonment status. Examples of these situations are:

a) Emergency disconnection: resulting from the unpredicted disconnection of the rig from the well, and operation resumption is planned/expected. Examples: blackout, LMRP disconnection due to loss of vessel position, among others;

b) Operational disconnection: predicted/planned disconnection when one or more equipment (BOP, BAP, WCT, CXT etc.) are disconnected from the well, but operational continuity (reconnection) without the rig leaving the location is predicted/planned. Examples: removal of BOP for the installation of a BAP or H-WXT and subsequent replacement of the BOP; removal of the BOP for subsequent installation of a XT, removal of the XT for subsequent installation of a BOP, replacement of the BAP, removal of the BOP for replacement/removal of the BAP or WXT, removal of the XT for subsequent connection of the riser hanger tool, among others.

For disconnection events during the offshore well construction stage, the provisions of the E&P Good Practices Notebook - Guidelines for Design and Construction of Offshore Wells, after published, must be considered.

For events during a temporary or permanent abandonment intervention stage of, the following must be considered:

i. Operational disconnection: the abandonment project should typically comply with the philosophy of two (2) independent WBs for isolation of the exploited formation to the external environment. For this purpose, the elements and acceptance criteria for temporary abandonment must be considered, allowing for criteria flexibility through a risk-based approach that indicates mitigation to the ALARP level considering the expected duration until reconnection to the well and/or installation of a new WB. Operational disconnection may be carried out with one (1) WB at ALARP risk level, through a risk analysis that considering the reliability level of the single WB in place, taking into account, for instance:

    1. Component elements of the WB;

    2. Adherence of the verification of WB elements to the acceptance criteria;

    3. Type of verification of the WB elements (whether by test or confirmation);

    4. Expected duration until reconnection to the well.

ii. Emergency disconnection: the project should seek to contemplate the provision (philosophy), during all the intervention, of two (2) independent WB for isolation of the formation exploited for the external environment. A risk-based approach indicating mitigation to the ALARP level must be adopted in cases of an emergency disconnection event with 1 (one) WB for isolation of the formation exploited for the external environment, caused by factors associated with the moment when such an event would be possible, due to the operation scenario or equipment limitation.

BOP retrieval for repair during a temporary or permanent abandonment well intervention does not fit to the situations above and must be considered as temporary abandonment.

3.2 Classification of temporary abandonments

Temporary abandonments can be classified into: monitored and unmonitored.

a) Monitored temporary abandonment: applies to temporarily abandoned wells that are periodically monitored and verified, according to the E&P Good Practices Booklet – Guidelines for Monitoring Wells in Temporary Abandonment. There is no time limit for this abandonment status;

b) Unmonitored temporary abandonment: applies to temporarily abandoned wells without periodic monitoring and verification. A well in a situation of unmonitored temporary abandonment should not remain over three (3) years in this situation, unless the established WBs meet permanent abandonment guidelines. In case of uncertainty about the duration of the unmonitored temporary abandonment or expectation of no future well reentry, it is recommended to perform the abandonment following permanent abandonment guidelines.

3.3 Temporary WB

The temporary WB is an envelope of one or more barrier elements that prevents unacceptable flow, to address the isolation needs identified in 2.1. The elements that compose a temporary WB do not need to be located at the same depth.

3.4 Temporary WB elements

Temporary WB elements should follow the respective EAC tables (refer to 6.2) and provide isolation in at least one flow direction, in order to, together with other element(s), constitute an WB. Examples of temporary WB elements are:

- Casing or liner;
- Production tubing;
- Mechanical plug inside the tubing or casing (mechanical plugs, PBP, RBP, subsurface valves, among others);
- Equipment installed to provide sealing at the wellhead (WXT, CXT, PAB, among others);
- Solid mechanical barrier for the tubing or casing annulus (liner packer, ECP, expandable packer, production packer, AMB, wellhead sealing element, among others);
- All permanent WB elements (cement plugs, cemented casings, among others).

Permanent WB elements composing a temporary WB must meet the length requirements described in 4.3.2.

For dry completed wells without natural flow ability to surface during the entire temporary abandonment duration, the absence of natural flow ability from the formation can be considered as a temporary WB element.

For subsea wells without natural flow ability to the seabed and, where applicable, to the surface, throughout the temporary abandonment duration, the absence of natural flow ability from the formation can be considered as a temporary WB element.

3.5 Temporary WB requirements

The Operator must evaluate and define the type and suitability of any temporary WB element which will be installed in the temporary abandonment. These elements must be designed, selected and suitable observing the following:

- The expected duration of temporary abandonment;
- The subsurface environment;
- The formations drilled;
- The fluids contained in the formations with flow potential which must be isolated;
- The maximum imposed pressure differential across the barrier, considering possible fluid migration from the formation, depletion and injection into the reservoirs;
- The expected temperatures during the temporary abandonment period;
- The possibility to verify the position/location of the element and its integrity by monitoring, considering the access and type of element, when applicable and required;
- Any specific conditions for future well reentry.

Any temporary WB that may subsequently be used as a permanent WB, when no longer there is interest in utilizing the well, must meet the requirements of the permanent abandonment guidelines.

Without impairment to the quantities of WBs indicated in Section 2, the installation of an WB within the last cemented casing is required if no WB is provided for the cased hole section.

Note: In offshore wells, this WB can be dismissed if the well has not progressed beyond the first drilling section.

For temporary abandonment, in general, the requirements for WB elements apply equally for primary and secondary WB. However, considerations regarding the difference in the expected exposure of the respective WB to formation fluids allow the operator to adopt differentiated requirements for the secondary WB. A typical example is the difference in metallurgy allowed for production/injection tubing and casing, since the first, according to EAC Table 10, must have metallurgy compatible to constant contact with the formation fluids during the abandonment period.

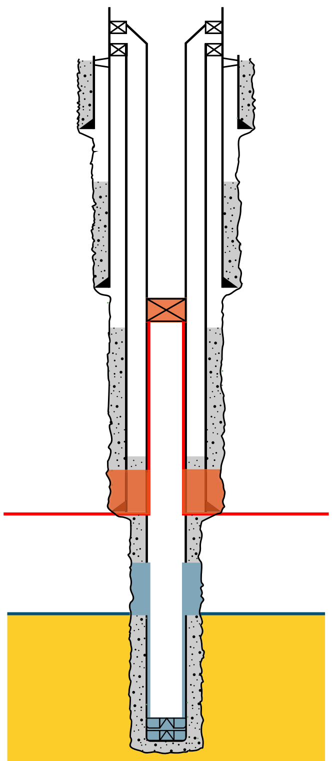
3.6 Typical temporary abandonment scenarios

There is a variety of situations in which a well may be temporarily abandoned. In normal conditions, temporary abandonment occurs after drilling, after a drill-stem test, completion, workover and/or in the case where permanent abandonment intervention is splited into stages.

For illustration purposes, examples to compose WB for temporary abandonment in several situations are shown below. The tables next to the WB diagrams identify the elements of each WB and the reference to its corresponding acceptance criteria table (see 6.2).

In many cases, wells are temporarily abandoned after the installation of the production casing or liner.

Figure 3 – Example of temporary abandonment after installation of the production casing for a natural flowing well

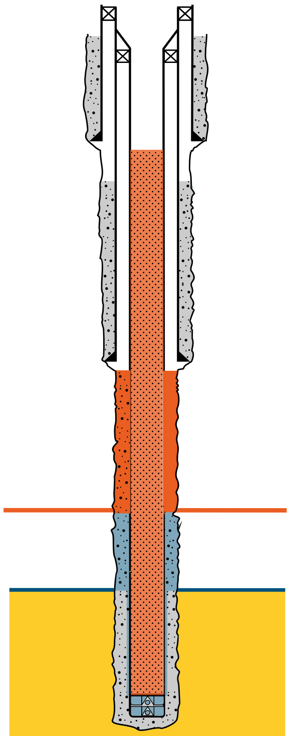


WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cemented *Shoe Track*	7
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Cement Plug or Mechanical Plug	3 or 23

Source: Prepared by the Authors.

Figure 4 exemplifies the temporary abandonment of a well without natural flow ability after the casing or production liner installation.

Figure 4 – Example of temporary abandonment of a non-natural flowing cased well



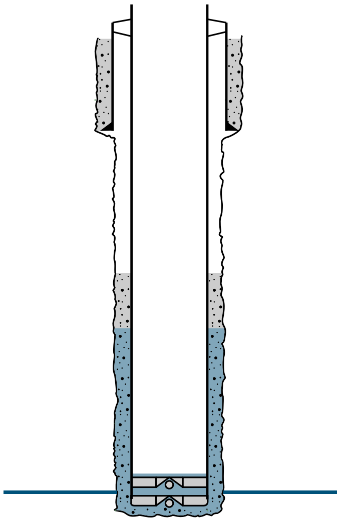
WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cemented Shoe Track	7
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Absence of flow	1

Source: Prepared by the Authors.

During the initial well construction sections or if no pertinent intervals are identified, it is possible to temporarily abandon a well having only 1 (one) WB installed, as shown in Figure 5. An example of this situation is the temporary abandonment after the execution of a top hole drilling (in offshore wells, this corresponds to drilling sections without BOP). In offshore wells, this WB can be dismissed if only Section #1 of the well was constructed, since typically unconsolidated formations are drilled.

For the elements of this WB in top hole drilling scenarios, acceptance criteria other than those exposed in the EAC tables in item 6.2 may be defined and adopted by the operators, considering the lower level of risk exposure and particularities of the elements used in this specific scenario.

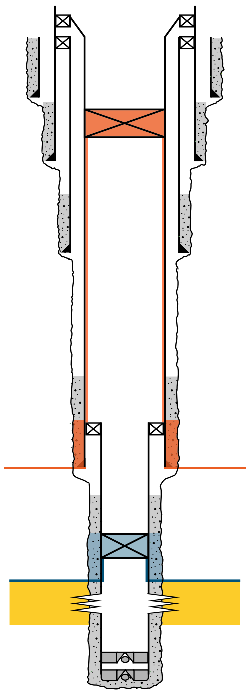
Figure 5 – Example of temporary abandonment of a cased well without pertinent intervals



WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cemented Shoe Track	7

Source: Prepared by the Authors.

Figure 6 – Example of temporary abandonment after drill-stem test

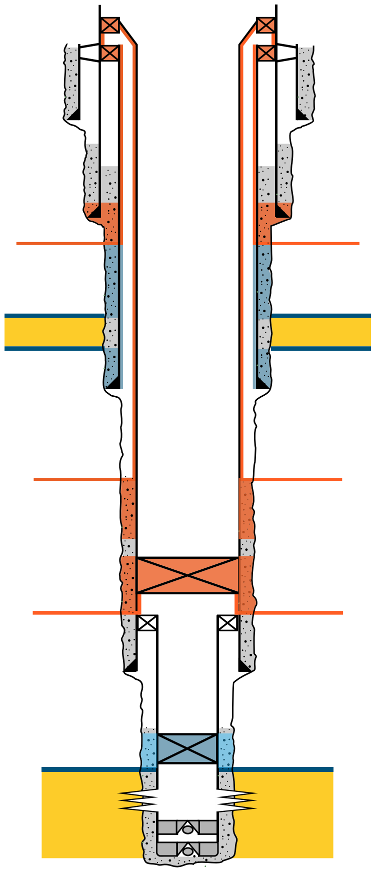


WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug or Mechanical Plug	3 or 23
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Cement Plug or Mechanical Plug	3 or 23

Source: Prepared by the Authors.

Figure 7 exemplifies a temporary abandonment configuration after a drill-stem test in which there is a shallower interval isolated by 2 temporary WB.

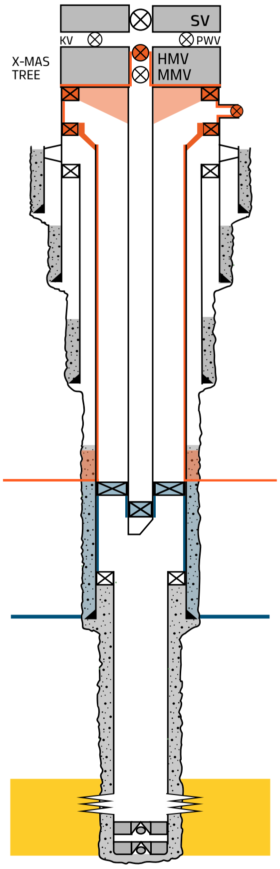
Figure 7 – Example of temporary abandonment after a drill-stem test with two intervals to be isolated



WB Elements	Table of Item 6.2
Primary WB (Deeper Interval)	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug or Mechanical Plug	3
Secondary WB (Deeper Interval)	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug or Mechanical Plug	3 or 23
Primary WB (Shallower Interval)	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Cemented Casing	2.5
Sealing formation (caprock)	8
Secondary WB (Shallower Interval)	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Wellhead	24
Casing	2
Cemented Casing	2.5
Sealing formation (caprock)	8

Source: Prepared by the Authors

Figure 8 – Example of temporary abandonment of a completed well with 1 zone, with DXT

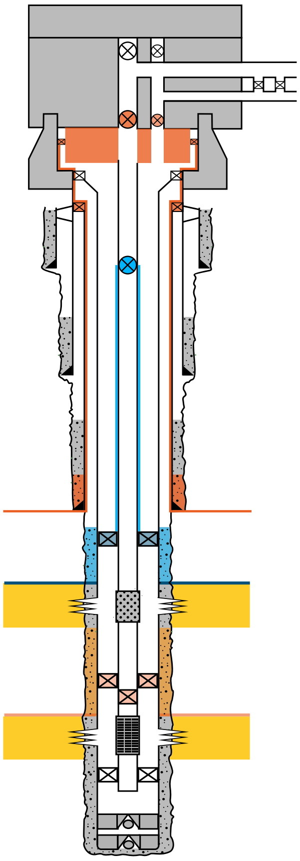


WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing (until the production packer)	2.5
Production *Packer*	15
Production String (from *Packer* to the Mechanical Plug)	10
Production String Mechanical Plug	12
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Wellhead	24
Production Casing Hanger	11
Dry Christmas tree (DXT)	28

Source: Prepared by the Authors.

Figure 9 exemplifies a temporary abandonment configuration for a well completed in 2 zones having a WXT installed, in addition to an WB to isolate in-between zones, which can also be considered as the primary WB for the lower interval.

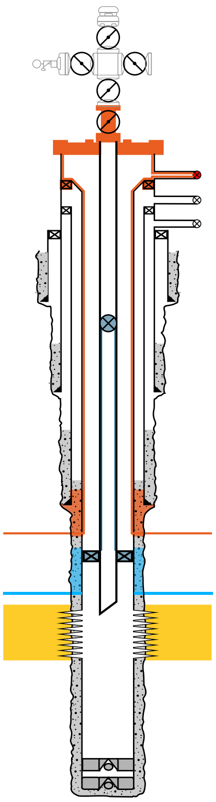
Figure 9 – Example of temporary abandonment of a well completed in 2 zones, with WXT



WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing (until the production packer)	2.5
Production *Packer*	15
Production Tubing (from *Packer* to the DHSV)	10
DHSV	20
Secondary WB	
Sealing formation (caprock)	8
Cemented Sealing formation (caprock)	2.5
Casing	2
Wellhead	24
Production Casing Hanger	11
Production Adapter Base (PAB)	25
Wet Christmas tree (WXT)	27
WB for Isolation between Zones	
Sealing formation (caprock)	8
Cemented Casing (until the production *packer*)	2.5
Packer	15
Production Tubing (from *Packer* to Mechanical Plug)	10
Production Tubing Mechanical Plug	12

Source: Prepared by the Authors.

Figure 10 – Example of temporary abandonment in a natural flowing onshore perforated well

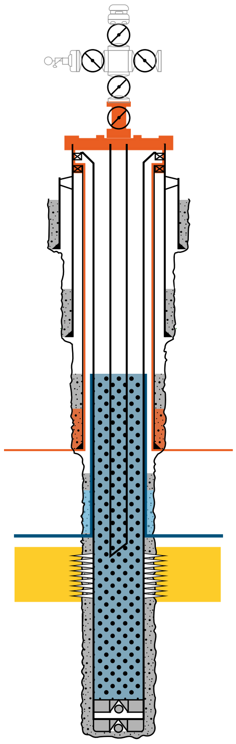


WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing (until the production packer)	2.5
Production *Packer*	15
Production Tubing (from *Packer* to the DHSV)	8
DHSV	20
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Wellhead	24
Production Casing Hanger	11
Wellhead Annulus Access Valve	19
Dry Christmas tree (DXT)	28

Source: Prepared by the Authors.

In Figures 11 and 12, it can be seen that the absence of natural flow ability acts one of the WB elements.

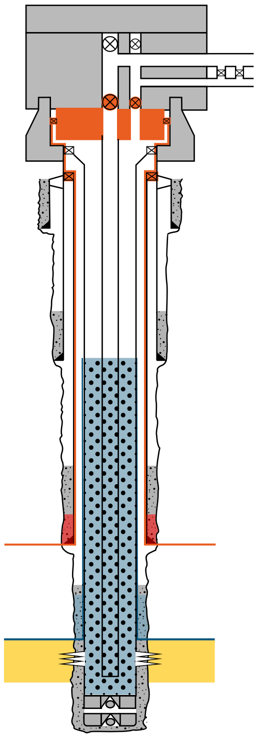
Figure 11 – Example of temporary abandonment in a non-natural flowing onshore well



WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Well without natural flow	1
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Wellhead	24
Production Casing Hanger	11
Dry Christmas tree (DXT)	28

Source: Prepared by the Authors.

Figure 12 – Example of temporary abandonment of a non-natural flowing offshore subsea well

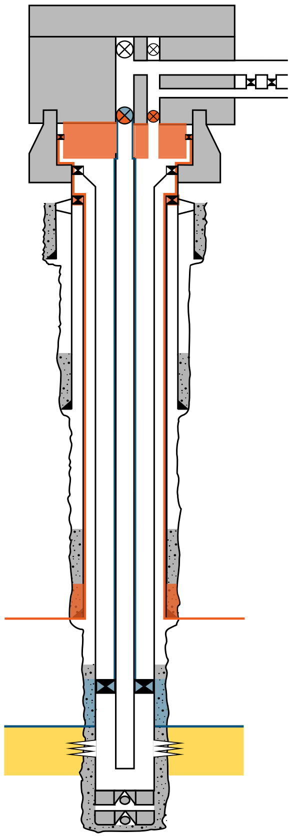


WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Absence of natural flow	1
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Wellhead	24
Production Adapter Base (PAB)	25
Production Casing Hanger	11
Wet Christmas tree (WXT)	27

Source: Prepared by the Authors

In exceptional situations, it may be necessary to temporarily abandon a well with shared WB elements, subject to a specific risk analysis. Figure 13 shows an example of a producing offshore natural flowing well having shared WB element, caused, for instance, by DHSV failure.

Figure 13 – Example of temporary abandonment of an offshore well with shared WB elements



WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Production *Packer*	15
Production Tubing (from the packer to its hanger)	10
Production Tubing Hanger	11
Wet Christmas tree (WXT)	27
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Casing	2
Wellhead	24
Production Adapter Base (PAB)	25
Production Casing Hanger	11
Wet Christmas tree (WXT)	27

Source: Prepared by the Authors.

4 PERMANENT WELL ABANDONMENT

Wells shall be designed, constructed and maintained so that they can be permanently abandoned.

Permanent WBs shall be established to isolate and prevent unacceptable flow, in response to the isolation requirements identified in Section 2.1. When composing permanent WBs, the WBEs must be positioned to provide isolation and the interconnection of these elements must have their bases at the same given depth. These elements must be made of consolidated plugging materials that do not deteriorate over time, and/or creeping formations that present sealing capacity of the annular space, being admitted the utilization of metallic tubulars (casing and tubing) between them.

In permanent abandonment of onshore wells offshore wells where casings, conductor and well head must be removed, additional operations are required, as described below:

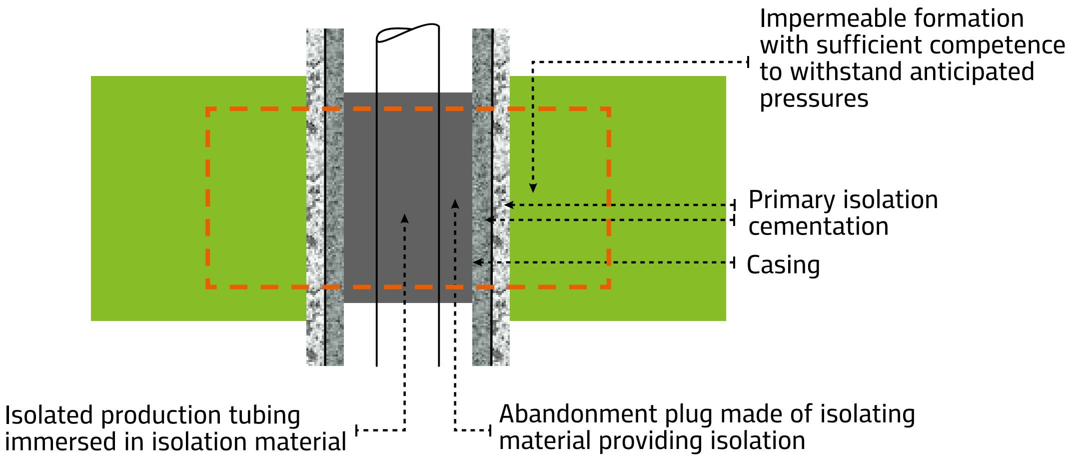
- For onshore wells, a surface cement plug of at least 60 m must be positioned with its top seated at the cellar and without the need for verification. In addition, for the well head removal, the casing and conductor should be cut off at the cellar;
- For offshore wells, a surface cement plug of at least 60 m must be positioned below the depth where the casing will be cut and without the need for verification (see Figure 30).

If the operator decides to verify this plug, the required length can be reduced to 30 m.

4.1 Permanent WBs

The philosophy of permanent WBs is to restore the original seal provided by the sealing formation (caprock), as shown in Figure 14, where the main elements of the permanent WBs are shown.

Figure 14 – Schematic of a permanent WB showing the restoration of the sealing formation (caprock)

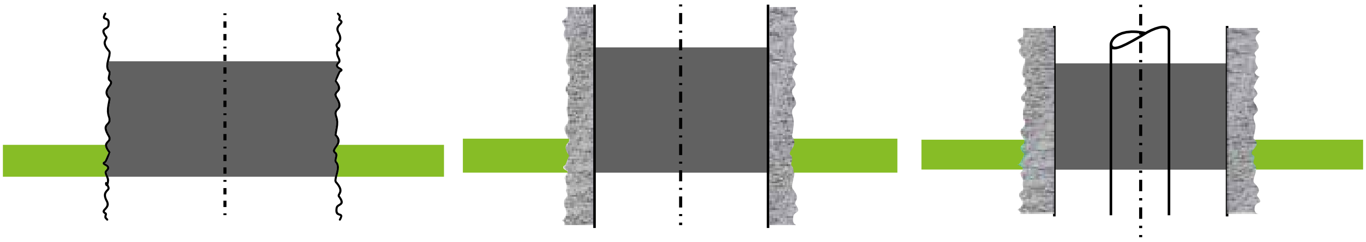


Source: Prepared by the Authors.

To achieve greater reliability in the installation of the permanent WB, it must be considered good plugging practices related to aspects such as: sufficient element length to compensate for the effects of contamination during its placement; definition of the base of the elements as a function of the sealing formation location and the element in the annulus(i) at the respective section; degree of pipe eccentricity in the WB section; cleaning and preparation of contact surfaces of the selected section to ensure proper interface between the elements; suitability of the elements for the well environment (presence of CO2, H2S, pressure, temperature, etc.).

At the base of the permanent WB, there shall be a sealing formation adhering to EAC table 8 (see Section 6.2) to prevent fluid migration through the formation leak-path. It should be ensured that the elements in the tubulars annuli and the element inside the smallest diameter tubing or open hole are complying to their respective EAC tables and acting to prevent flow through the wellbore, as per Figure 15. The cement slurry (or alternative material with similar performance) used in well plugging, after hardened, acts as an WB element.

Figure 15 – Example of permanent WBs: (a) in open hole section; (b) in cased and cemented hole section; (c) in a section with production tubing



Source: Prepared by the Authors.

The possibility of leakage through the tubing body or coupling associated with localized incomplete filling by the cement slurry in the annulus means that the hardened cement slurry present in the cemented annular casing is generally not considered to be a suitable permanent WB element to prevent radial flow of fluids from the formation into the wellbore and from the wellbore into the formation. However, it can be considered a suitable permanent WB element for flow through the annulus provided there its length and cement annulus quality verification.

In general, cables and control/injection lines should not be part of permanent WBs along their entire length. However, cables and control/injection lines can be present in permanent WB, through a risk-based approach, mitigating the existence of potential leak paths to an ALARP risk level (see 5.11.1).

As a rule, any subsurface equipment that could cause loss of integrity of the permanent WB should be removed. As an example, elastomers used as sealing components in some WB elements are not acceptable as permanent WB elements.

4.2 Materials for permanent WB elements

Plugging materials used in the composition of WB elements must present the following characteristics, in a present and future perspective:

- Result in a barrier with low permeability to prevent unintentional flow through the WB element by meeting at least one of the following criteria:
  - water permeability less than or equal to 5 μD;
  - water permeability less than or equal to 1 thousandth of the permeability of the pertinent interval to be isolated;

  - combination of element permeability and length, resulting in the ability to prevent migration equal to or greater than that of the sealing formation (caprock);
  - combination of element permeability and length, resulting in the ability to prevent migration equal to or greater than that of a 30 m long cement plug.
- Provide hydraulic seal at interfaces to prevent fluid flow around the WB element. The material shall provide a seal along interfaces with adjacent materials such as metallic tubulars and the formation. The risks of volumetric shrinkage while curing and bond strength reduction, if relevant, shall be considered;
- Remain at the intended position and well depth;
- Maintain long-term integrity by not deteriorating its properties over time after exposure to the well environment conditions. This will include bottomhole pressures, temperature, and chemical environment that may exist;
- Resistant to formation fluids (e.g., CO_2, H_2S, hydrocarbons, brines) under the anticipated downhole temperature and pressure conditions;
- Provide adequate mechanical properties to withstand mechanical stresses and temperature and pressure changes, including operational changes during the well lifecycle.

Portland cement and other dry-blended cementing mixtures are the commonly applied materials that constitute the elements of the permanent WB in the annuli and inside the tubulars. However, alternative materials with different principles of action are under continuous development by the industry and can be used, upon prior qualification to be applied in permanent abandonment, being the Operator responsible for establishing the qualification process that concludes the similarity of effectiveness in comparison to the barrier consisting of Portland cement and its dry cementing mixtures, through compliance to the previously indicated requirements.

4.3 Requirements for permanent WB elements

For permanent abandonment, WB element requirements apply equally to primary and secondary WB.

4.3.1 Positioning requirements

The permanent WB elements must:

- Have geometrically coincident bases seated at the planned depth to constitute an WB;
- Exist in the inside and in the annuli of the tubulars along the cross section;
- Have their bases placed across a sealing formation (caprock) according to the EAC 8 table.

The operator shall assess and, as the case may be, mitigate risks of compaction or subsidence on the integrity of the permanent WB.

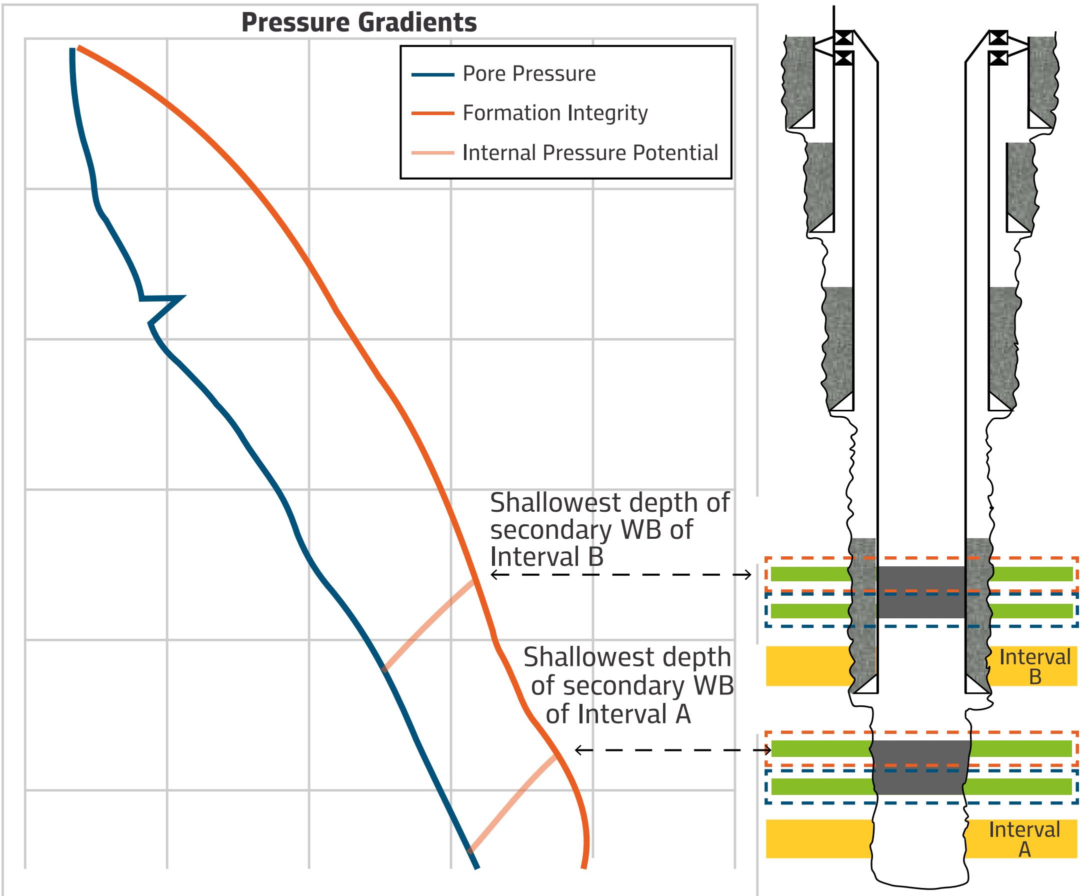
The primary and secondary permanent WB can be established as 1 (one) single combined WB with the function of two (2) separate WBs.

In situations where the base of the cement plug is significantly above the interval with potential inflow (e.g. installed above the top of the production packer), it must be verified if the fracture pressure of the formations on the base of the WB element is greater than the maximum anticipated internal pressure, from a current and future perspective, so that sealing formation can act as an WB element.

Figure 16 shows the positioning philosophy for WBs considering wellbore pore pressure, formation integrity, and anticipated internal pressure. In this Figure, the shallowest possible depth for the base of the secondary WB of each interval to be isolated is indicated.

It is also shown that the integrity of the shallower formation sealing (above interval B) cannot withstand the potential internal pressure of the deeper interval (interval A). The two deepest WBs isolate this interval to the surface, while the other two are suitable only for the shallowest interval (interval B).

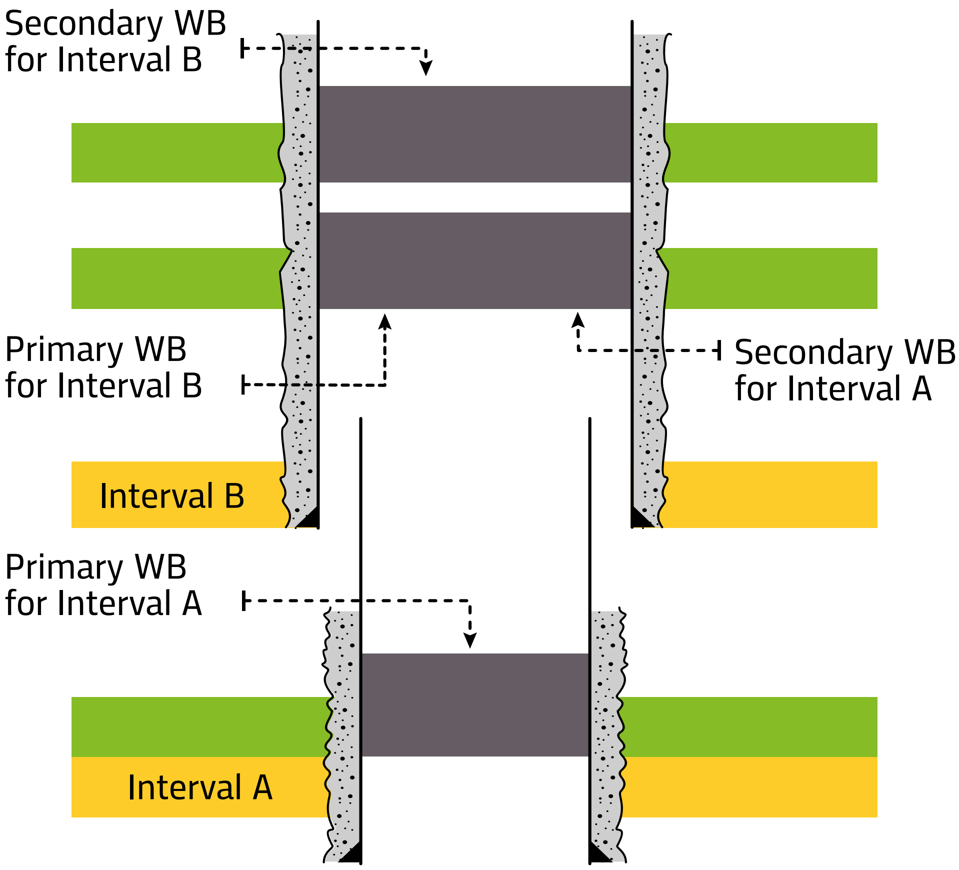
Figure 16 – Philosophy for permanent WB positioning



Source: Prepared by the Authors.

Figure 17 exemplifies a situation with two intervals having flow potential that must be isolated from each other and to the surface.

Figure 17 – General requirement for permanent abandonment with two intervals to isolate



Source: Prepared by the Authors.

For the cement (or alternative barrier material) plug, placed above the top of a liner without a cemented overlap above an interval with non-negligible geological uncertainty of the pertinent interval characterization (see 4.3.3), it is recommended that the positioning requirements in 4.3.1 are met, even this plug not being considered an official WB.

4.3.2 Length requirements

The length of the WB elements must meet the provisions of their respective EAC tables.

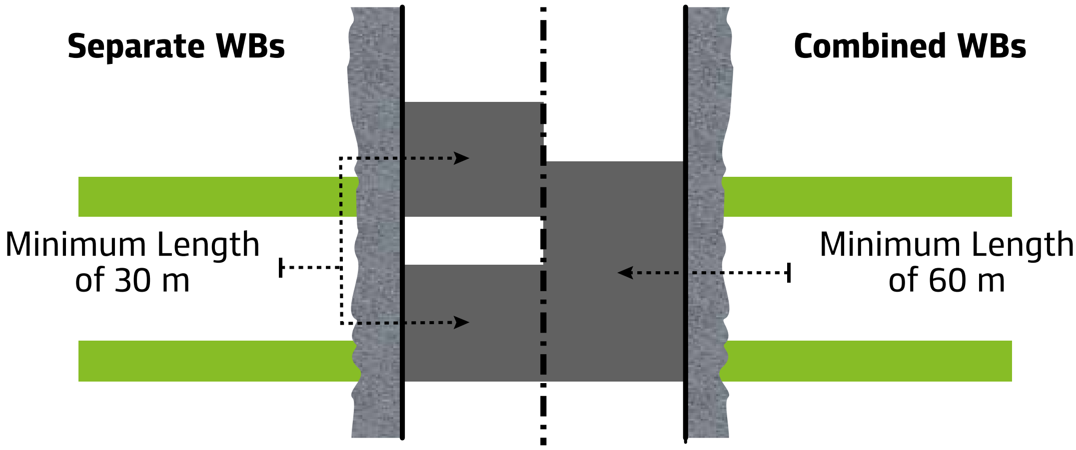
For elements based on the application of cement or alternative material subject to contamination, to achieve higher reliability of the permanent WB element, the planned length for placement operations of cement or alternative material should be greater than the minimum length required for an WB element.

For Combined WBs, there should be no reduction considered to the length of the theoretical primary and secondary WB, and therefore twice the length indicated in the respective EAC tables must be considered for each WB element.

In case there are pertinent intervals separated by less than 30 m which analysis indicates the need for isolation to prevent cross flow (see item 2.1), the maximum possible WB element length should be seated between these intervals.

In case the sealing formation (caprock) above the upper interval is unable to withstand the anticipated internal pressure of the lower interval, it must be considered that the WB established between these intervals meets, exceptionally – due to a limitation imposed by nature – the concept of a combined WB.

Figure 18 – Cement plug length comparison for separate and combined WBs, for a cased and cemented well



Source: Prepared by the Authors.

4.3.2.1 Reduced length of barrier elements and/or WB

The minimum length required for WB elements in their respective EAC tables are based on historical industry practice, seeking to cover all existing wells and, at the same time, to absorb uncertainties that would lead to obtaining an effective length shorter than the minimum nominal length of the WB.

This prescriptive approach seeks to establish baselines, but it must be noted that, technically, differences between geometries, pressure differentials, materials or additives used and characteristics of the formations are determining factors for the proper functionality required for the WB element.

To exemplify, it could be mentioned the WB element 'cement plug' (see Table 3), where a minimum length of 30 m is required. Considering a simplified formulation to determine the theoretical required cement bond length:

Δp = *pressure differential across the cement plug*

A_t = *cross-sectional area of the cement plug*

A_{lat} = *area of the cement plug that is bonded to the casing inner wall*

τ = *bond strength between cement plug and casing inner wall*

D = *internal diameter of the casing in which the plug is installed*

Force applied on the cement plug $= F_{apl} = \Delta p \times A_t$

Strength supported by the cement plug $= F_{sup} = \tau \times A_{lat}$

$$A_t = \frac{\pi}{4} \times D^2$$
$$A_{lat} = \pi \times D \times L$$

In the limit situation before failure, the force to which the cement plug would be subjected would equal the force supported by its bonding to the casing inner wall:

$$F_{apl} = F_{sup}$$
$$\Delta p \times A_t = \tau \times A_{lat}$$
$$\Delta p \times \frac{\pi}{4} \times D^2 = \tau \times \pi \times D \times L$$

Therefore, the minimum required bonded length for this element could be estimated as:

$$L = \frac{\Delta p \times D}{4 \times \tau}$$

Therefore, for instance, to withstand a 1,000 psi pressure differential, a cement plug installed inside a casing with an 8.5" internal diameter and 50 psi bond strength would require a 42.5" (1.08 m) bonded length.

On the other hand, changing the pressure differential to 6,000 psi, in a casing with an internal diameter of 12.3" and bond strength of 30 psi, would require 615" (15.6 m) bonded length.

Likewise, for the WB element 'annulus cement' (Table 5), a similar formulation, considering the simplification of bonding only at the interface cement x casing:

Δp = *pressure differential across the cement in annulus*

A_t = *cross-sectional area of the cement in annulus*

A_{lat} = *area of the annular cement bonded to the casing external wall*

τ = *bond strength between the cement in annulus and the casing external wall*

D = *diameter of the drilled section in which the annulus cement is installed*

d = *external diameter of the casing in which the annulus cement is installed*

Force applied on the cement plug $= F_{apl} = \Delta p \times A_t$

Strength supported by the cement plug $= F_{sup} = \tau \times A_{lat}$

$$A_t = \frac{\pi}{4} \times (D^2 - d^2)$$
$$A_{lat} = \pi \times d \times L$$

In the limit situation before failure, the force to which the annular cement would be subjected would equal the force supported by its bonding capacity to the casing external wall:

$$F_{apl} = F_{sup}$$
$$\Delta p \times A_t = \tau \times A_{lat}$$
$$\Delta p \times \frac{\pi}{4} \times (D^2 - d^2) = \tau \times \pi \times d \times L$$

Therefore, the minimum required bonded length for this element could be estimated by:

$$L = \frac{\Delta p \times (D^2 - d^2)}{4 \times \tau \times d}$$

Thus, for instance, to withstand a pressure differential of 1,000 psi, the annulus cement installed between a 9.6" OD casing facing a 12.25" drilled section, with 50 psi bond strength, would require a 30.2" (0.77 m) bonded cement length.

On the other hand, changing the pressure differential to 6,000 psi, on a 9.6" OD casing versus a 14.75" section and 30 psi bond stress would require a bonded cement length of 653.1" (16.6 m).

This simplified approach shows that different stress levels act on WB elements according to each specific well condition. Thus, there is room for the operator, through an appropriate risk-based approach, to evaluate the effectiveness and adopt WB element lengths shorter than those indicated in the respective EAC tables. In this analysis, aspects such as the following must be considered:

- Anticipated internal pressure acting on the WB element;
- Geometry of the WB elements and their interfaces;
- Quality, properties and integrity of the WB element component material;
- Bond strength and/or resistance strength at the interfaces of the WB element with other elements;
- Characteristics of the adjacent sealing formation (caprock) (mechanical strength, presence of fractures or surrounding faults);
- Temperature and chemical effects acting on the element;
- Potential new leak paths entailed by the shorter length.

This analysis should be documented and referenced as an acceptance criterion for the WB element length in the specific case.

4.3.3 Open hole requirements

The requirements set out in item 2 apply to any pertinent interval in the open hole section.

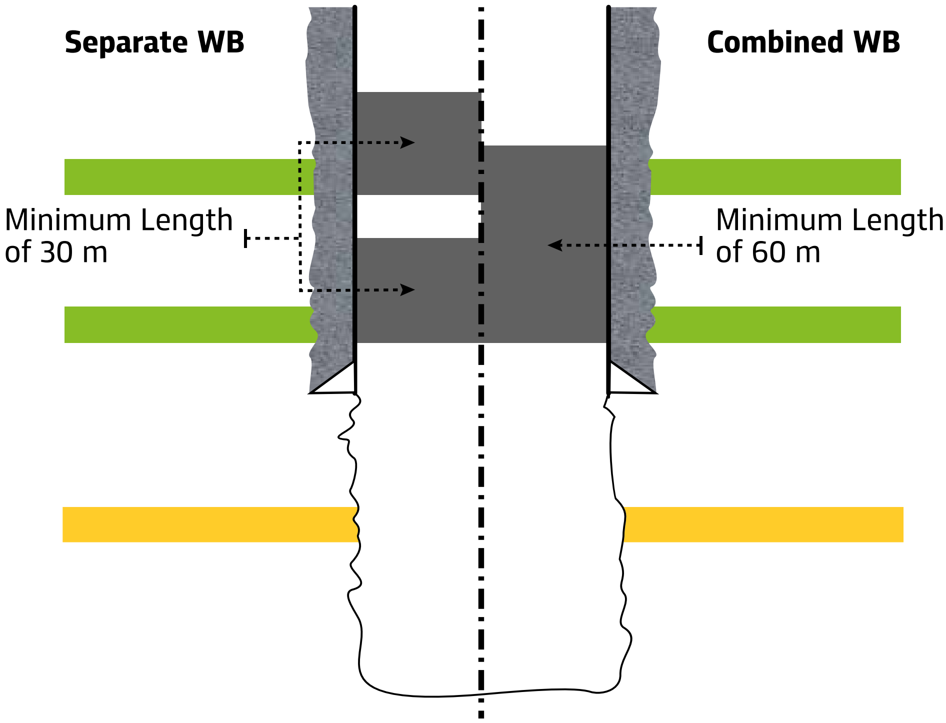
Without impairment to the WB quantity stated in item 2, a permanent WB is required to be placed within the last cemented casing or at the open hole/cased hole transition if no WB is provided in cased hole.

Note: In offshore well, this WB may be dismissed if, additionally, the well is not drilled beyond the first section.

In case there is a liner with an uncemented overlap, above an interval with non-negligible geological uncertainty regarding the pertinent interval characterization, a cement plug or a plug of alternative material should also be placed above the liner top. This plug is not an official WB but will serve to isolate any exposed formation below the overlap into the wellbore and must be verified.

Figure 19 exemplifies separate or combined permanent WB sets for the isolation of open hole intervals with flow potential, if the anticipated internal pressure does not exceed the fracture pressure of the exposed formations in the open hole section and the cased hole up to the base of the secondary WB.

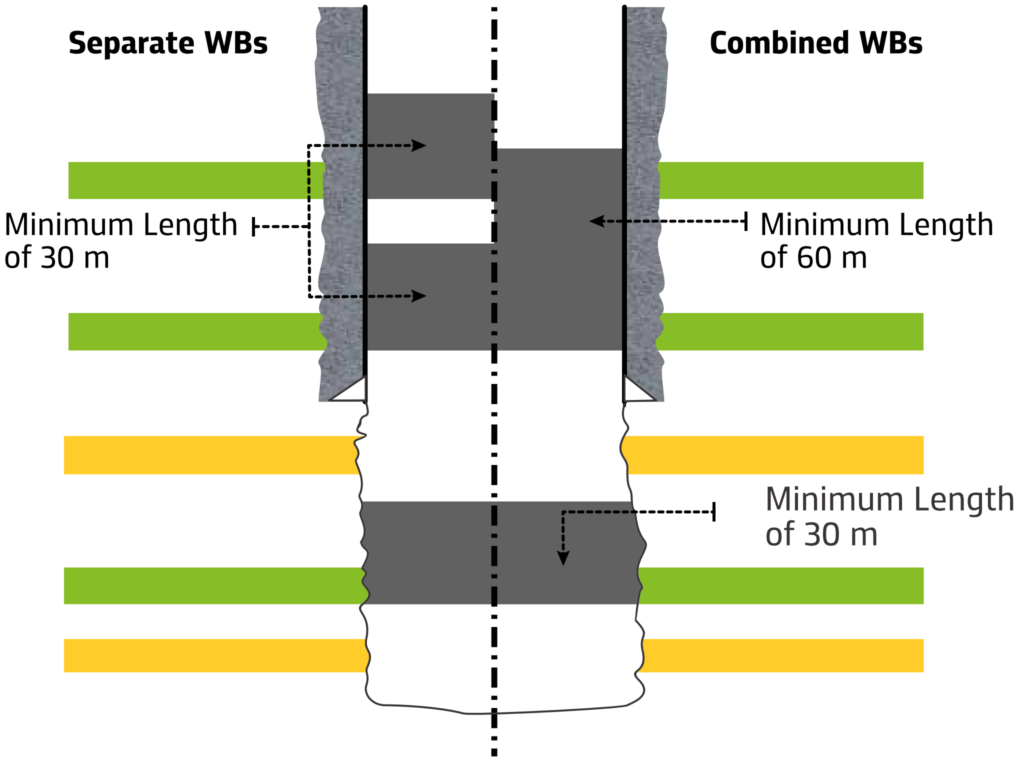
Figure 19 – Example of permanent separate and combined WB to isolate an open hole interval with flow potential



Source: Prepared by the Authors.

The intervals with flow potential in the open hole section not naturally connected with cross-flow deemed as unacceptable (see item 2.1) shall be isolated from each other by 1 (one) permanent WB, as per Figure 20.

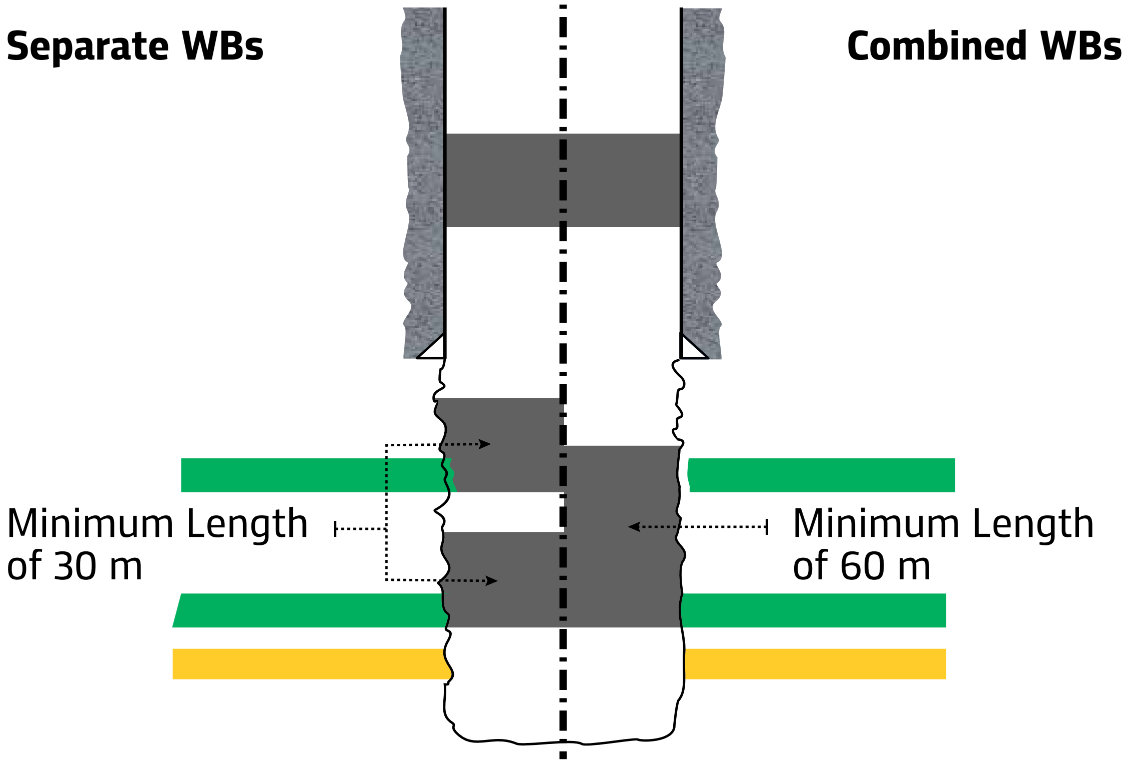
Figure 20 – Example of permanent WB in open hole for isolation between zones



Source: Prepared by the Authors.

In case of formations with anticipated internal pressure capable of fracturing the last casing shoe or any formation below it, at least two (2) permanent separate or combined WBs should be installed between the top of the interval with flow potential and the last casing shoe or the base of the formation at risk of fracturing in the open hole section, whichever is deeper.

Figure 21 – Example of permanent WBs in open hole when the anticipated internal pressure of the interval exceeds the fracture pressure of the last casing shoe



Source: Prepared by the Authors.

4.3.4 Cased hole requirements

The requirements set forth in item 2 are applicable to any existing interval with flow potential in the cased hole section.

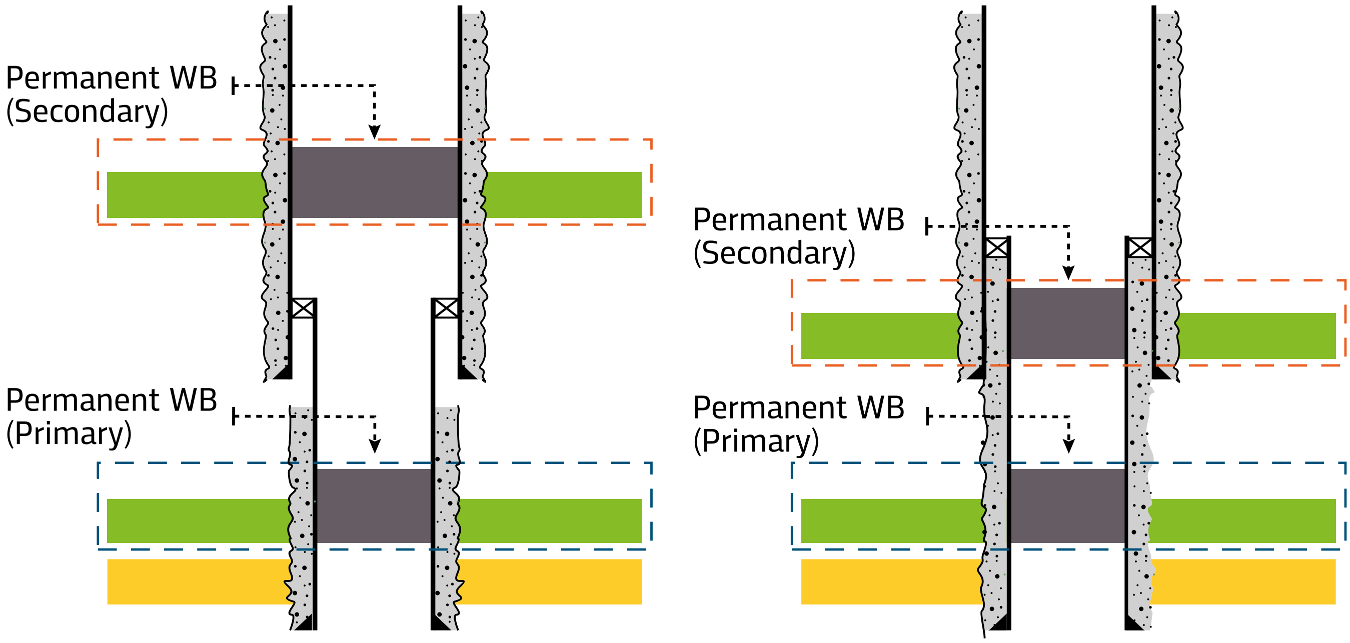
Isolation of the top of liner with a cement plug or a plug with alternative material is not mandatory, without impairment to the remaining abandonment procedures, in case:

» It is possible to install, between the top of the liner and the top of the pertinent interval, the required WBs to isolate from the external environment and, where applicable, between formations;

» The liner overlap is cemented or the risk of presence of a pertinent interval in the well section between the casing shoe and the top of cement in the liner annulus is negligible (see 4.3.3).

Figure 22 shows two variations, with configuration (a) where the secondary WB was installed above the top of the liner, in order to mitigate geologic uncertainty risks from the uncemented overlap section, while in configuration (b) both WB were established inside the liner.

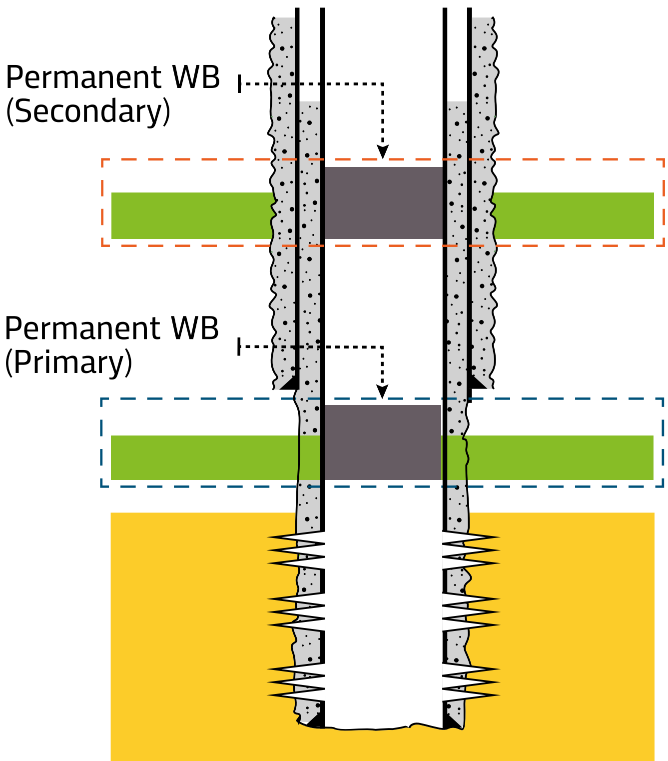
Figure 22 – Examples of WBs for permanent abandonment of well equipped with liner



Source: Prepared by the Authors.

In the case of a perforated (slotted) liner, two (2) permanent WBs should be installed above the top of the pertinent interval, as shown in Figure 23.

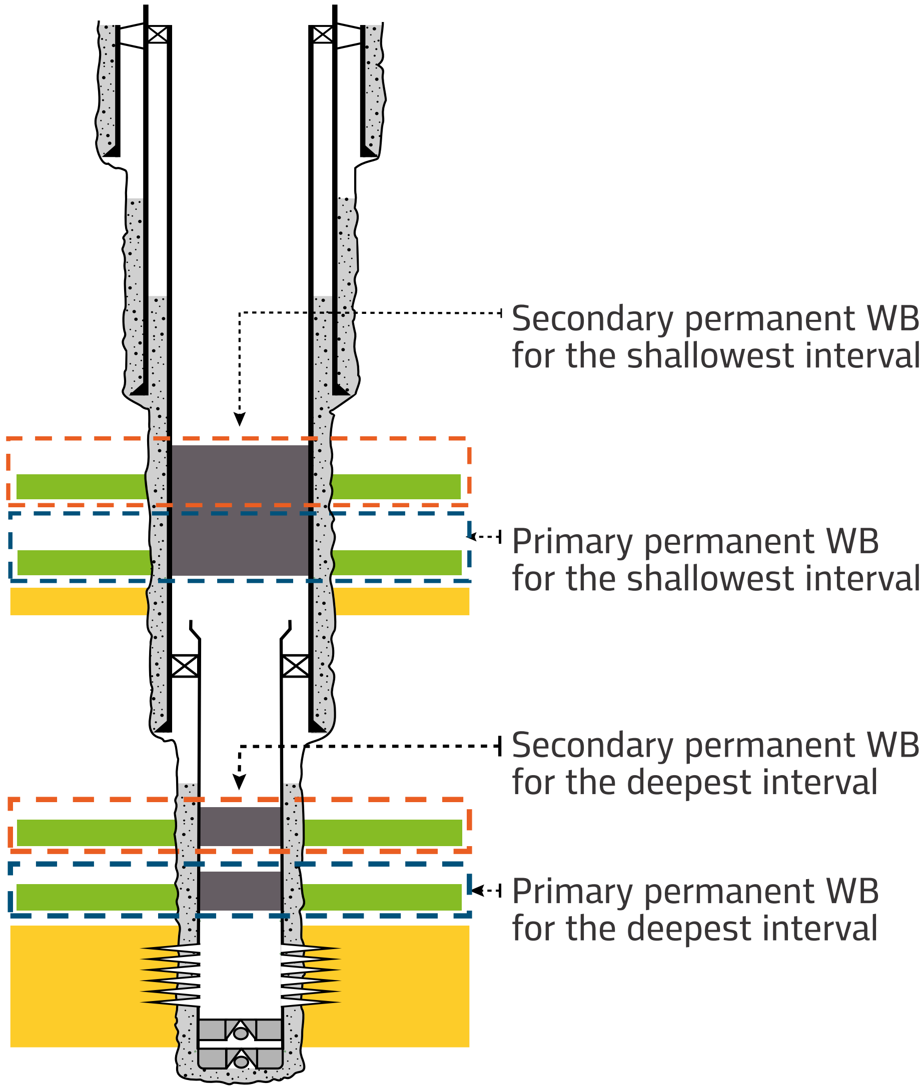
Figure 23 – Examples of WBs for permanent abandonment of a perforated well



Source: Prepared by the Authors.

Permanent WBs sealing formation, including those installed in a cased hole, must have sufficient strength to withstand the anticipated internal pressure of the formation to be isolated (see 4.3.1). Figure 24 shows a permanently abandoned well in which the sealing formation comprising the two (2) shallowest WBs are not capable of withstanding the maximum anticipated internal pressure of the deepest interval.

Figure 24 – Examples of WB installed when the shallowest WB is not capable of withstanding the anticipated internal pressure of the deepest interval



Source: Prepared by the Authors.

In cases where the WB element in the casing annulus/annuli does not meet the criteria established in the respective EAC Table, a need for additional operations to install a new barrier or to remediate this element during well abandonment intervention may be required.

Such recomposition of the element in the required annuli can be executed in several ways:

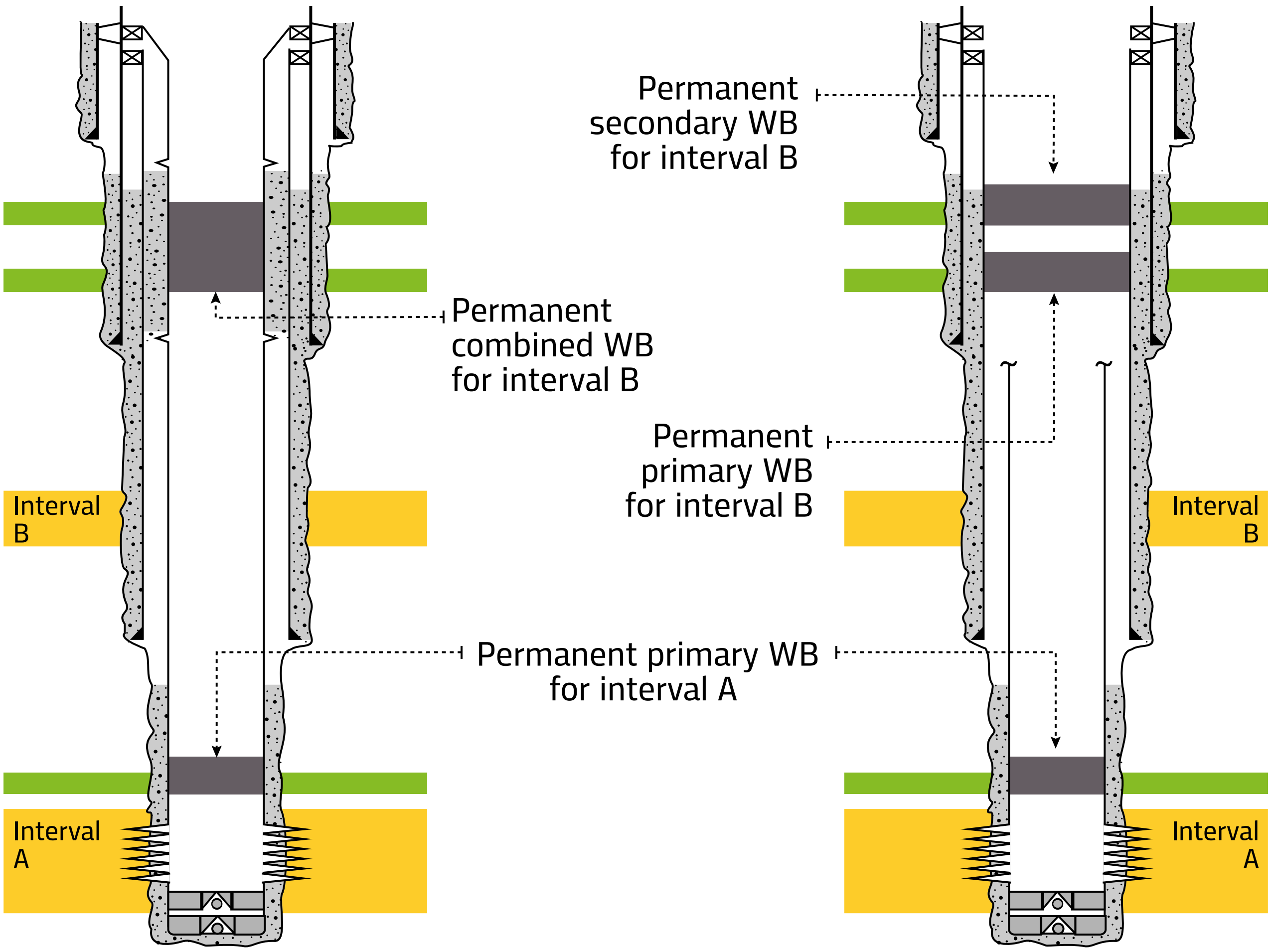
- perforating and recementing the relevant section;
- cutting and removing the casing to allow the placement of the plug above the cutoff point (see item 5.7);

» milling a section of the casing to expose the annulus and allow the placement of a cement plug or alternative material plug within this section (see item 5.8);

» perforate, wash and cement placement in the pertinent section; a method commonly known as PWC (see item 5.9).

Figure 25 shows abandoned wells using the recementing and casing cut-and-retrieve method.

Figure 25 – Examples of WBs seated by recementing and liner cutting and removal



Source: Prepared by the Authors.

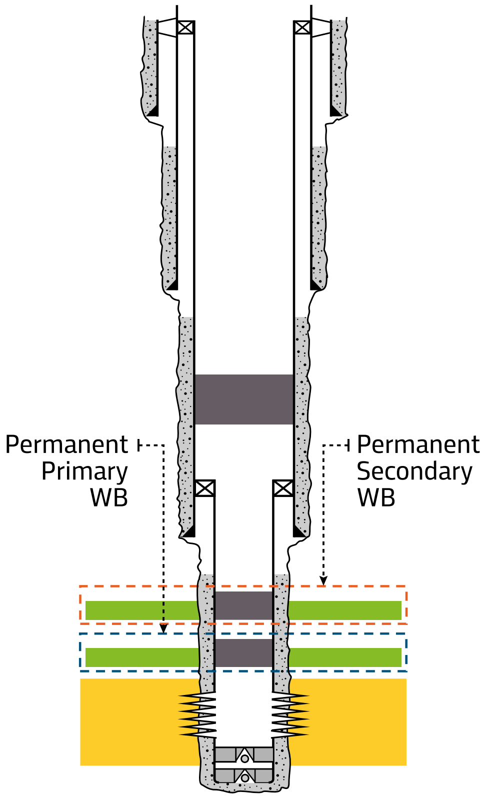
4.4 Typical permanent abandonment scenarios

Under usual conditions, a well is permanently abandoned after the end of its productive lifetime (production/injection wells) or after drilling (non-commercial exploratory wells or wells for data acquisition purposes).

For illustration purposes, examples of WBs for permanent abandonment in some situations are shown below. The tables next to the WB diagram identify the elements of each WB and its corresponding element acceptance criteria (EAC) reference Table (see Section 6.2).

Figure 26 shows an example of a configuration for permanent abandonment WBs in a well with a perforated casing across an interval with flow potential, and non-negligible geological uncertainty in the well section between the casing shoe and the top of the cementing in the liner annulus.

Figure 26 – Example of permanent abandonment of a perforated well

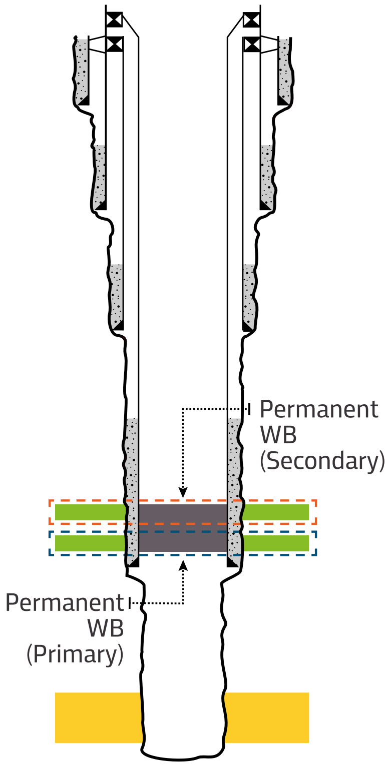


WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug	3
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug	3

Source: Prepared by the Authors.

Figure 27 shows a permanent abandonment schematic after drilling, with a single pertinent interval in the open hole section. The formations above the pertinent interval up to the Secondary WB base have adequate mechanical strength to withstand the potential internal pressure of the interval with flow potential. Should the potential internal pressure exceed the strength of the formations below the casing shoe, the WBs would have to be installed in the open hole section, as shown in Figure 21.

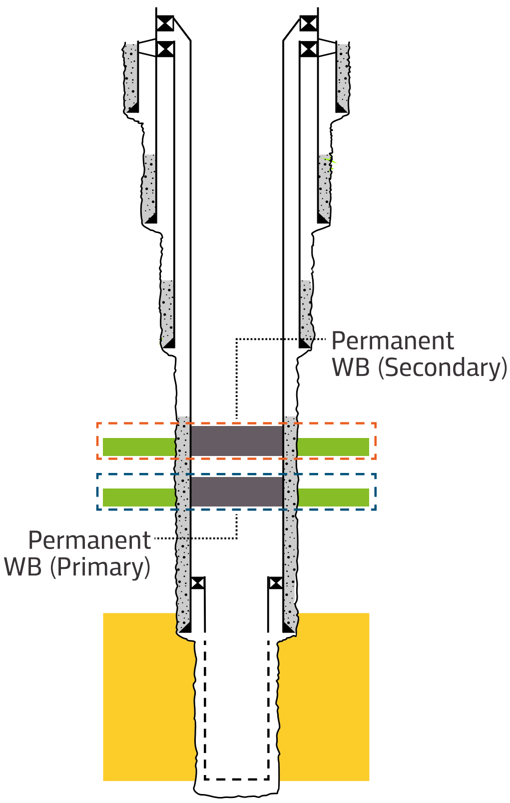
Figure 27 – Example of permanent abandonment after drilling, isolation an interval with flow potential in open hole



WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug	3
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug	3

Source: Prepared by the Authors.

Figure 28 – Example of permanent abandonment of a well with slotted liner or with screens



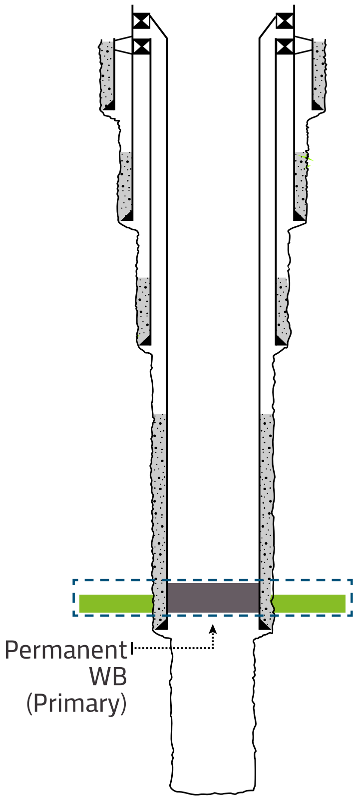
WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug	3
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug	3

Source: Prepared by the Authors.

In specific situations where no pertinent intervals were drilled (in the case of dry exploratory wells, for instance), abandonment can be done with only one (1) WB installed in cased hole, as shown in Figure 29.

For the elements of this WB, acceptance criteria different from those exposed in the EAC Tables in section 6.2 may be defined and adopted by the operators, considering the lower level of risk exposure and particularities of the elements used in this specific scenario.

Figure 29 – Example of permanent abandonment of a well without intervals to be isolated

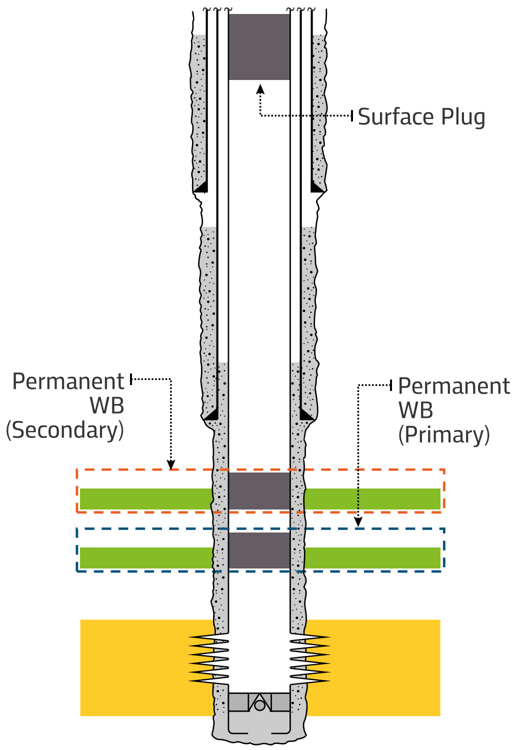


WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug	3

Source: Prepared by the Authors.

Permanent abandonment of onshore or offshore wells located in water depths up to a 100 m is completed with the installation and verification of the required permanent WBs. However, to complete decommissioning operations, removal of the wellhead, cutting the casing to the wellhead base (for onshore wells) or 3 m below the seabed (for offshore wells in water depths up to 100 m), and installation of the surface plug, as illustrated in Figure 30, must be carried out.

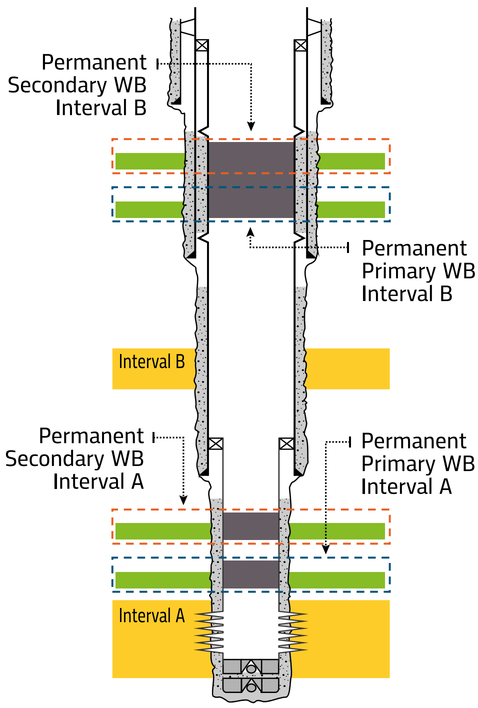
Figure 30 – Example of permanent abandonment of an onshore well



WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2,5
Cement Plug	3
Secondary WB	
Sealing formation (caprock)	8
Cemented Casing	2,5
Cement Plug	3

Source: Prepared by the Authors.

Figure 31 – Example of permanent abandonment for a well with 2 intervals to be isolated. The WBs for the upper interval were obtained by recementing the casing



WB Elements	Table of Item 6.2
Primary WB (Interval A)	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug	3
Secondary WB (Interval A)	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug	3
Primary WB (Interval B)	
Sealing formation (caprock)	8
Cemented Casing (Phase 2)	2.5
Cemented Casing (Phase 3)	2.5
Cement Plug	3
Secondary WB (Interval B)	
Sealing formation (caprock)	8
Cemented Casing (Phase 2)	2.5
Cemented Casing (Phase 3)	2.5
Cement Plug	3

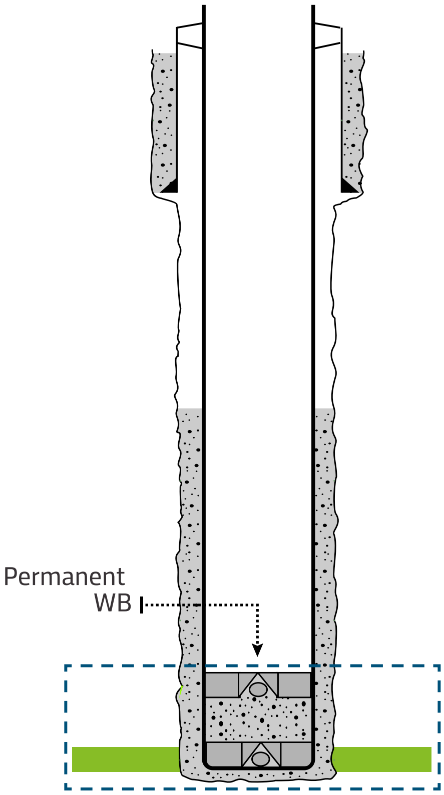
Source: Prepared by the Authors.

In the construction of the first well sections without evidenced pertinent intervals, permanent abandonment with only 1 (one) WB can be executed, as shown in Figure 32. An example of this situation is the permanent abandonment after top hole drilling (in offshore wells, this corresponds to the riserless drilling sections, i.e. without BOP).

In offshore wells, this WB can be dismissed if only Section 1 of the well was constructed, since typically unconsolidated formations are drilled. In this sense, it is recommended that this section should not be cased in order to enable well walls to naturally collapse.

For this WB, elements and acceptance criteria different from those exposed in the EAC Tables in item 6.2 may be defined and adopted by the operator, considering the lower risk exposure level and particularities of the elements used in this specific scenario.

Figure 32 – Example of permanent abandonment of a cased well without pertinent intervals



WB Elements	Table of Item 6.2
Primary WB	
Sealing formation (caprock)	8
Cemented Casing	2.5
Cement Plug or Shoe Track	3

Source: Prepared by the Authors.

5 SPECIAL SITUATIONS

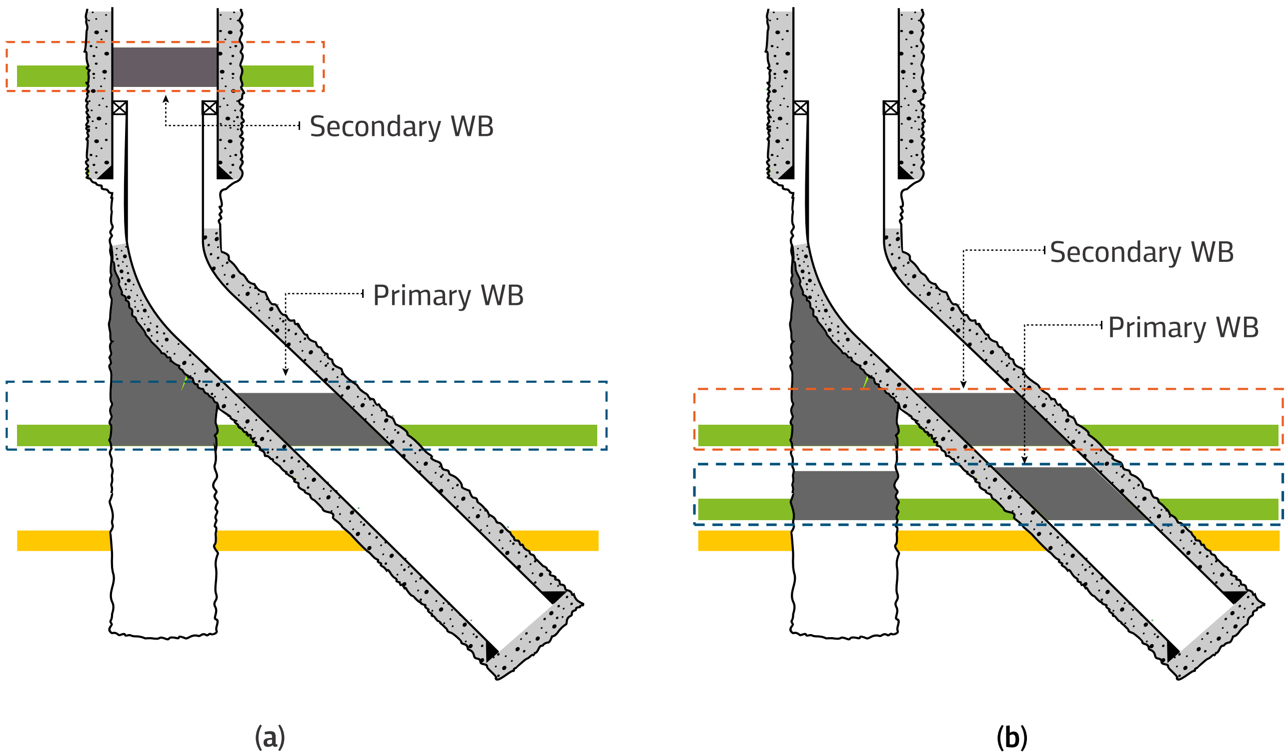
5.1 Sidetracking

The abandonment of the original well must be carried out in accordance with the guidelines in this document unless there is a high level of confidence that the WB for this section can be installed and verified during the permanent abandonment of the sidetrack.

No sidetrack should be carried out on a permanent WB element unless the length of the cement plug is of sufficient size, so that the integrity of this WB is not compromised (see Section 4.3.2).

Figure 33 shows examples where there is one (1) common WB above the sidetrack depth, plus one (1) independent WB on each track of the well to isolate the interval with flow potential (Figure 33a) and two (2) independent WB on each track (Figure 33b).

Figure 33 – Examples of WB configurations in sidetracked wells: (a) with 1 common WB above the sidetrack depth; (b) with 2 separate WB in each track



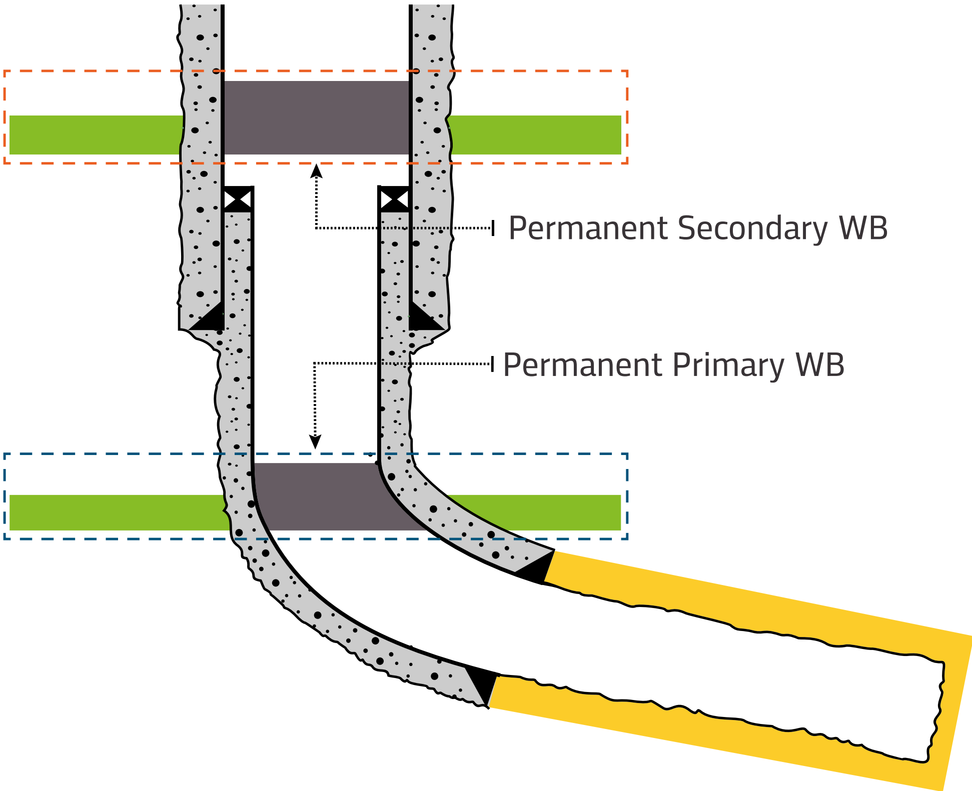
Source: Prepared by the Authors.

5.2 Horizontal wells or highly deviated wells (> 70⁰)

In principle, the abandonment requirements for a horizontal or highly deviated well do not differ from those for a vertical well. The difficulty lies in the means to ensure satisfactory isolation, usually more difficult to be achieved in horizontal or highly deviated well sections.

Horizontal and highly deviated well sections present additional difficulties to achieve isolation because the deviation makes it difficult to satisfactorily place cement slurry in the section. Alternative additives and materials can be used in an effort to maximize the likelihood of successfully installing the permanent WB elements. Figure 34 shows a case with only one pertinent interval in a highly deviated well section.

Figure 34 – Example of permanent WB in a highly deviated well



Source: Prepared by the Authors.

5.3 Multilateral wells

For multilateral wells, the provisions of this document must be applied for each of the sections/tracks.

For multilateral wells, attention should be given regarding:

» Possible difficulty in accessing some of the sidetracks(s); in case this becomes necessary for the proper establishment of a permanent WB;

» Possibility of different pressure regimes in the various tracks.

It is possible to establish a permanent WB on the main section common to two or more sidetracks, as exemplified in the sidetracked well scenario (Figure 33), if the WB elements meet their respective acceptance and positioning criteria.

5.4 Shallow overpressured intervals and investigation wells

Every shallow overpressured interval must have its isolation requirement evaluated according to item 2.1, considering the type of fluid as well as its capacity to sustain the flow up to the point of making it deemed unacceptable. If a need for isolation of this interval to the external environment is indicated, two (2) permanent WBs must be established, without impairment to the installation of other WBs and/ or plugs required according to this Good Practice Booklet.

For the permanent abandonment of an investigation well, firstly the objectives of such a well must be identified. If one of its objectives is the investigation of shallow hazards existence, entailed from uncertainty of the area to be drilled, the following barriers must be installed in addition to other WBs and/or plugs required in this Good Practices Booklet:

- Two (2) permanent WBs verified by tag or other confirmation methods (visual inspection confirming flow absence after installation of the WB), if a pertinent interval was drilled;
- A cement plug, with a minimum length of 60 m, if there are no pertinent intervals effectively identified at the time of well abandonment. In such case, verification of the plug is not required.

  This cement plug should be installed at the well bottom, to mitigate the risk of shallow hazards near (below) the final depth where drilling has ended, or in a shallower section, if uncertainty persists as to the existence of a pertinent interval in the drilled section.

In case of an offshore well which exclusive objective is to explore other (non-shallow hazards) characteristics of the formations, such as, for instance, geomechanical aspects, and the drilling did not cross an interval with flow potential or aquifer, the cement plug is not required. In such cases, it is recommended that, at the end of the drilling operation, a fluid is displaced into the well to stimulate the natural collapse of the formations into the wellbore.

5.5 Hydrocarbons of biogenic nature

The compounds of biogenic nature are originated in shallow formations, being the direct result of organic matter decomposition and subject to occur in any oil field. Unlike thermogenic hydrocarbons, which underwent temperature and pressure effects, due to load from the overburden, biogenic hydrocarbons are generated at a depth of a few tenths of meters and, in most cases, are methane. If found around the wells, hydrocarbons of biogenic origin do not necessarily indicate failure of an WB element and in such case there would be no action required by the operator. The differentiation between thermogenic and biogenic can be made by chemical analyses (the most suitable method), comparing the hydrocarbons in the vicinity with those found in the well.

5.6 Fluid spills

Leaks and spills are undesirable events and do not necessarily indicate failure of an WB element. Situations such as poor cleaning above the shallowest WB elements, fluid accumulation in cavities released during equipment disconnection, or fluid release due to friction between surfaces are possible to occur, during and/or after abandonment intervention, and should be addressed using the ALARP approach.

Therefore, the operator, besides proceeding with the incident communication according to the prevailing rules in effect, must identify and implement the most appropriate alternative to be followed, based on the evaluation of aspects such as:

- fluid type;
- intensity of the leakage/spill;
- potential damage to people and the environment;
- WB elements installed;

- verifications carried out on the WB elements;
- effort to inspect the evolution of the event;
- effort to act, stop the event, and conclude operations.

5.7 Creeping formations

Certain types of geologic formations (for instance, certain shales and saline formations) are known for their mobility. Such formations are capable to seal a non-cemented annulus space. Normally, such mobility is a geologic characteristic observed along the field and not only restricted to a certain well. To be considered as an WB element, the plastic formation (or creeping formation) must meet the criteria established in EAC Table 9.

If the formation is assessed to be geologically homogeneous and presenting lateral continuity, then it can be qualified, allowing in subsequent wells in the area, to simplify the WB element verification process as defined in Table 9.

5.8 Casing cut and retrieve

In situations where annulus isolation is not assured by the annulus cement, one of the options is the cutting and retrieval of the casing to enable the installation of an WB above cutting depth (see section 4.3.4).

Prior to cutting, it is important to check for presence of entrapped gas, or pressured fluids behind the casing, or unbalance that may generate false kick indications.

Casings are typically anchored under tension. After being cut, the uncemented portion of the casing will release its accumulated tension and may cause the casing stump top to drop below the cutting depth. This casing stump movement and/or shock wave may release entrapped gas due to damage induced to the hardened cement sheath or the breakage of the annulus plugging material.

Once sufficient casing length is removed to enable WB installation on top of the cutting depth, the EAC tables for the respective elements to be installed must be followed.

5.9 Section milling

Section milling is used to get access to the annuli of one or more casings by destroying them along a certain length.

This method is applied as an alternative to installing or rebuilding the WB element in the annulus of the casing (see 4.3.4), so that only the WB element inside the well, typically a cement plug or a plug of alternative material needs to be installed to establish an WB.

Attention should be given regarding the assessment of metallic waste (swarf) resulting from the milling operation, which requires the capacity to remove it to the surface, as well as its separation, preventing it from being recirculated into the well. Furthermore, the risk that this swarf can pose to equipment installed in the well, including the drilling BOP, must be evaluated.

5.10 Perforate, Wash and Cement (PWC)

The PWC method is applicable to well scenarios where it is needed to establish or remediate the existing WB element in the annulus of the tubular(s) (see Section 4.3.4). In this method, a BHA is run to perform the three required operations, resulting in both the WB element in the annulus and inside the tubular(s):

- Perforate: stage where the entire length across which the WB will be installed is perforated so that the interior of the well and the annulus(i) are hydraulically communicated;
- Wash: stage where circulation/jetting is performed to remove the existing material from the annulus(i), leaving it in a suitable condition to have the WB element being installed in the third stage;
- Cement: stage where the cement slurry or alternative material is pumped and displaced, seeking that it satisfactorily fills the annulus(i) and the interior of the tubular(s).

To verify the effectiveness of the WB elements, the following must be considered:

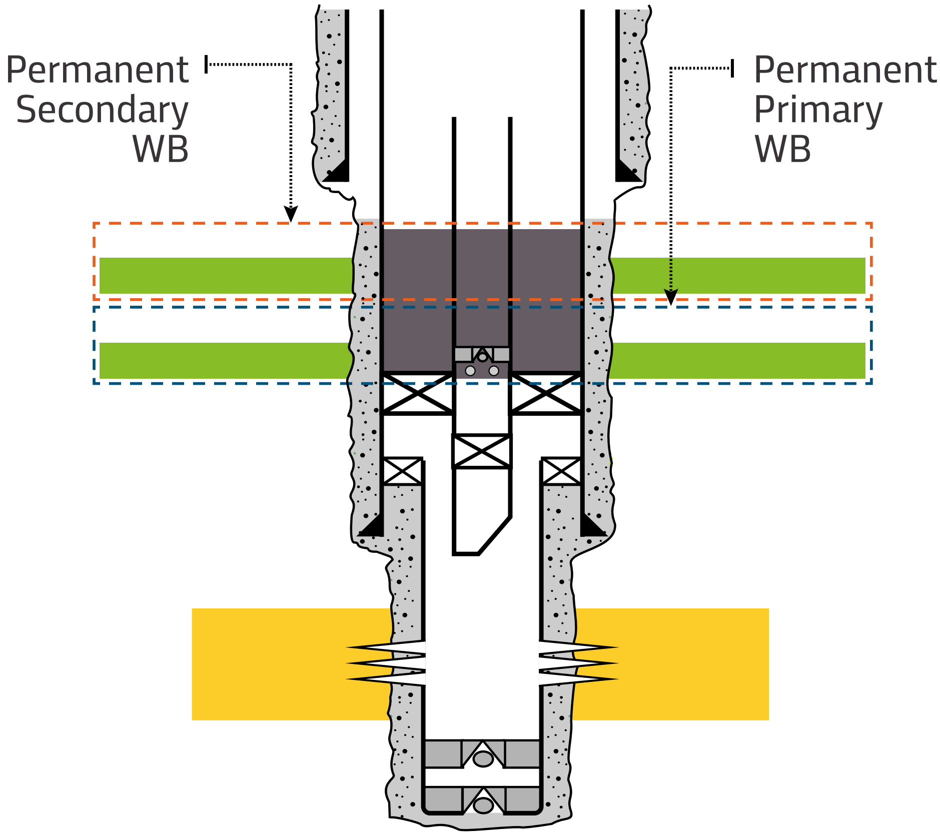
- Element inside the smallest diameter tubing: cement plug or alternative material, meeting respectively the EAC Tables 3 or 4;
- Element in annulus(i) of tubular(s): cement or alternative material in annulus installed by PWC, meeting EAC Table 31.

5.11 Through-tubing abandonment

The through-tubing abandonment method consists of establishing WBs through the production/injection tubing. In this scenario, part or all of the production/injection tubing remains in situ and WBs are formed by positioning permanent WB elements in the annulus between the tubing and the casing, as well as inside the tubing, in a section where cement had been verified in the annuli between the casings and sealing formation (caprock) and, if applicable, also between the casings.

WB elements installed in through-tubing operations both inside and in the tubular(s) annulus(i) must meet the criteria established in the respective EAC Tables (see Section 6.2). Figure 35 shows an example of through-tubing abandonment in cased hole.

Figure 35 – Example of through-tubing abandonment



Source: Prepared by the Authors.

5.11.1 Through-tubing abandonment in sections with gauge cables and/or control/chemical injection lines

Gauge cables and control/chemical injection lines might be part of a permanent WBs, throughout a risk-based approach where risks associated to the existence of potential leak paths are mitigated to an ALARP level.

The proposed condition for placing permanent WBs should be analyzed through a risk assessment that considers:

» Whether operations, prior to the placement of a permanent WB will be performed to:

  – ablate gauge cables and control/injection lines, eliminating their mechanical and hydraulic continuity; or

  – plugging of the control/chemical injection lines in the sections where permanent WBs will be installed; or

  – total destruction (section milling) of the tubing interval, together with the gauge cables and control/chemical injection lines, by applying novel technologies such as thermite chemical reaction heaters, plasma or laser cutting.

» The gauge cable and control/chemical injection lines length that will remain in the permanent WB;

» The length of the proposed permanent WBs;

- The proposed positioning and verification methods of the WB elements;
- The type of cables and/or lines, e.g. ESP cable, PDG cable, chemical injection line, control line;
- The encapsulating material of the cable and/or control/chemical injection line;
- The degradation analysis of the cable and/or control/chemical injection line materials, taking into consideration temperature and fluid environment;
- The existence of damage to the cable and/or control/chemical injection line during installation or operation;
- The materials that will be used to provide the required isolation in the vicinity of the cables and/or control/chemical injection lines. Alternative barrier materials and properties, including self-healing, may be considered;
- The materials that will be used to isolate within the control/chemical injection lines;
- Possible leak paths through interfaces between materials and the inside of control/chemical injection lines;
- Leakage failure modes.

In case the operator does not previously remove the cables and control/chemical injection lines from the sections where the permanent WBs will be installed, but after a technical assessment – applying good industry practices – the operator concludes the feasibility of permanent through tubing abandonment in these sections, this decision must be previously agreed with by the regulator, in view of the current existing rules in the SGIP Technical Regulation.

5.12 Permanent abandonment with open water production/injection tubing removal

The permanent abandonment method with open water production/injection tubing removal is an alternative method to remove well equipment and install permanent WBs without the utilization of the drilling BOP system.

It should be emphasized that, although drilling BOP is not used, the general requirement for 2 independent WBs during all stages of the permanent abandonment intervention remains, which includes the period of open sea operations.

This method has the potential to enable permanent abandonment intervention, where production tubing removal is required, in complex scenarios such as:

- Wells with weakened well structure or old wells with restricted information available about the well structure strength, making the installation of the drilling BOP assembly not recommended due to such uncertainties;
- Wells whose riser analysis indicates excessive stress induced by the BOP drilling system over the well structure;
- Wells in shallow water depths (WD) utilizing a dynamic positioning (DP) unit, mitigating impacts of operations on an environmentally sensitive seabed or with mooring difficulties due to the presence of subsea obstacles.

The method also presents some advantages compared to the operation performed through the inside of the drilling BOP system, which makes it potentially advantageous even in cases where this system could be used. In this sense, one can list:

» Mitigation of operational risks for tubing hanger removal: prevents debris from drilling riser joints falling onto the production/injection tubing hanger; allows visual monitoring and auxiliary interventions with ROV (for cleaning, for instance), as well as enabling a more accurate diagnosis of situations where the tubing is not released;

» Mitigation of personal/occupational risks: avoids the need for cleaning and handling operations of riser joints at the surface, eliminates installation and removal maneuvers of BOPs and drilling risers.

To apply this method, the operator must consider risks involved and establish mitigating actions, considering the unavailability of the drilling BOP and the WBs that will be in place during open sea operations.

5.13 Riserless interventions

The initial stages of an abandonment intervention in subsea wells completed up to the Christmas tree can be performed using one of two philosophies:

i. *Riser based:* where the system that links the intervention unit to the well is of the rigid type, making use of workover risers, such as, for instance, Drill Pipe Riser (DPR), dual bore riser or concentric riser. In this system, mechanical access to the well occurs through the inside of these tubulars and typical surface pressure equipment are observed, usually composed of lubricators and BOP;

ii. *Riserless:* if there is no rigid system linking the intervention unit to the well. In this system, the pressure control equipment (lubricators and workover BOP) is of the subsea type, and therefore, the BHAs for mechanical well access, if applicable, are lowered along the water depth - which may contact with sea water - to the depth of the wellhead, when connection to the well is established.

Compared to the riser based system, the riserless system operation has potential advantages of reduced subsea wellhead stresses and reduced handling time with subsea intervention tools, but in both cases, the general requirement of two (2) independent WBs during all stages of the intervention remains.

The operator should evaluate the suitability between the riserless system proposed for the intervention and the intended scope, considering its possible limitations. In this sense, for instance, it may be concluded that a riserless system that does not allow coiled tubing operation is not suitable for the intervention in a specific well.

5.14 Radioactive sources trapped in the well

In case of loss of radioactive sources in the well, the company owning the radioactive source must communicate the fact to the National Nuclear Energy Commission (CNEN), in accordance with CNEN Resolution 252/2019 or any subsequent regulation, with the Operator also obligated to inform ANP, in accordance with the Manual for Communication of Oil and Natural Gas Exploration and Production Incidents.

Once the decision for isolating and abandoning the radioactive source in the well is taken, the Operator must communicate the decision of abandonment officially to the company owning the radioactive source, which, in turn, must advise and monitor the abandonment operation, as provided in Article 43 of CNEN Resolution 252/2019.

For abandonment, the radioactive source must be located as accurately as possible (inspection and verification) and must be isolated according to item IX of Art. 44, §1 of the aforementioned Resolution, with the main purpose of fixing the source in place and isolating it from potential fluid movement, without impairment to the installation of others WB and/or plugs required in this Good Practices Notebook:

"IX - thickness of the cement plug to be installed, with a minimum of 60 meters, for tools with gamma or neutron radiation emitting sources. For the case of abandonment of neutron generators, with tritium sources with activity under 1110 GBq (30 Ci), extensive cementation over the tool is not necessary, but this thickness should be defined in the installation procedure."

Whenever possible, some sort of deflection device (e.g., steel ball, used drill bit, etc.) must be placed on top of the plug, in order to prevent any future intent to reenter this section of the well for drilling.

5.15 Non-planned abandonment operations

In the execution of interventions for construction, maintenance, or temporary abandonment of a well, the Operator can find himself in a situation where the most appropriate technical and/or economic option is:

i. The temporary abandonment through the installation of permanent WBs;

ii. The temporary abandonment through the installation of temporary WBs, which may include execution operations that are difficult to be reverted;

iii. The permanent abandonment.

Considering the request for prior notification to the regulator in case of intention of permanent abandonment, prescribed in the SGIP Technical Regulation, conflicts may arise between operational performance necessary to maintain safety, the interpretation of the context and the deadline for meeting the regulatory requirement. In a general and indicative way, the operator must perform the steps below, not necessarily in the order presented, observing the principles of preserving personnel and environment safety, good faith, transparency with the regulator and economic considerations:

- Initiate a discussion with the regulator as soon as possible, seeking to clarify the identified possibility of well compromising;
- Prior to the start of the irreversible abandonment operation, proceed, if pertinent, with the submission of the required documentation to meet the regulatory requirements for permanent abandonment;
- Execute the most appropriate operation, technically and economically, having personnel, environmental, and operational safety as main priorities.

5.16 Applying the ALARP risk approach

As defined in the Technical Regulations for the Well Integrity Management System (SGIP/WIMS) and incorporated in this Good Practice Notebook, ALARP (As Low Reasonably Practicable) is defined as the "concept that risk reduction efforts should be continuous until the additional sacrifice (in terms of cost, time, effort, or other employment of resources) is vastly disproportionate to the additional risk reduction achieved".

Thus, to adhere to the ALARP concept, it is assumed that at least two scenarios are compared:

i. Interruption of the operations that had a certain objective, assuming the respective residual risks;

ii. Continuing operations to achieve this specific goal, incurring in an additional effort, seeking to mitigate the residual risks of the previous scenario.

This comparative evaluation between scenarios can be performed by means of qualitative, semi-quantitative or quantitative methodologies. Figure 36 shows a semi-quantitative methodology, which can be adjusted to the case evaluated, where aspects comparison must be established under the same logical rationale (for instance, the greater ➔ the worse), enabling the consolidation of results.

Figure 36 – Example of a methodology for comparative evaluation between different alternatives

			Alternatives					
Aspects		Weight	Alternative 1		Alternative 2		...	
			Score	Remarks	Score	Remarks	Score	Remarks
Residual Risk	Residual risk probability of...							
	Risk Severity of...							
WEIGHTED SCORE (∑ Weight x Score / ∑ Weight)								
Additional Sacrifice	Financial cost to implement the alternative							
	Time to implement the alternative							
	Technical effort to implement the alternative							
	Difficulty/ complexity to make available the resources required to implement the alternative							
	Probability of unsuccess to implement the alternative							
	...							
WEIGHTED SCORE (∑ Weight x Score / ∑ Weight)								

Source: Prepared by the Authors.

After a certain issue is evaluated, it is recommended that the operator set standards in order to maintain uniformity of decisions.

An example where the ALARP risk approach for decision making is applicable can be illustrated by the case where it is difficult or impossible to access the required depth to install the permanent WBs in compliance to the respective guidelines (see item 4). In this case, it is possible to evaluate the existing technical alternatives for abandonment, which may include unconventional options, such as, for instance, positioning barrier elements across a permeable or low consolidated formation. This option may prove to be the most appropriate in an ALARP risk approach to the extent that the risk of flow through such isolation is unlikely and/or of low severity, when compared to the effort and residual risks of other alternatives.

If the ALARP risk approach is identified as being the technically more appropriate option but contains a violation of a regulatory requirement, this shall be addressed with the regulator prior to its implementation.

5.17 WB element impairment

Cases in which the functionality of a barrier element is limited, but is still considered acceptable, should have the respective risk assessment or technical analysis that concluded for the acceptance documented and approved according to the level of competence established by the Operator.

6 WB ELEMENTS VERIFICATION

The position and effectiveness (seal) of the designed and installed WBs must be verified, according to the acceptance criteria set out in the respective EAC Table:

- At installation;
- In periodic monitoring, applicable for exclusively temporary WB element that has specific monitoring requirement (see item 6.2);
- If subjected to loads over its rated design capacity;
- After repair.

Verification is intended to confirm that the WB element is in position and that its integrity meets the purposes for which it was designed. Some previously installed WB elements, such as mechanical plugs, may have their sealing capacity compromised due to stresses imposed during the well life cycle caused by pressure and temperature variations and/or mechanical impacts.

The lack of WB element verification is unusual, and must be addressed through a risk-based approach that indicates mitigation to the ALARP level for the risks related to the uncertainty about the non-verified element. A typical example of this situation occurs in interventions for temporary abandonment where the intermediate casing is an WB element of a well whose B annulus is not accessible.

a) Position verification: indication that the element is installed at the expected depth/length. Usual methods:

   i. Confirmation by tagging: weight application on top of the WB element;

   ii. Confirmation by operational parameters: analysis of parameters acquired or monitored during the WB element installation;

   iii. Confirmation by logging: use of log that allows the inference by direct or indirect methods;

   iv. Confirmation by others (methods): other methods of confirmation that allow the inference of the positioning and that do not fit directly into the abovementioned sub-items. Example: geomechanical modeling for the sealing formation (caprock) strength analysis.

b) Seal verification: indication that the element presents capacity (potential and/or effective) to hinder the flow that is intended to be avoided. Usual methods:

   i. Test: pressure test carried out in the direction of the flow, considering a pressure differential at least equal to the maximum anticipated (see item 6.1);

   ii. Confirmation by pressure: application of a pressure differential to the WB element (see item 6.1);

   iii. Confirmation by operational parameters: analysis of parameters acquired or monitored during the WB element installation;

   iv. Confirmation by logging: use of log that allows the inference by direct or indirect methods;

v. Confirmation by others (methods): other methods of confirmation that allow the inference of the sealing ability that do not directly meet the previous sub-items. Example: lithological analysis of a sealing formation (caprock).

The specific seal verification may be inconclusive and therefore dismissed, provided that the WB element meets the following positioning conditions:

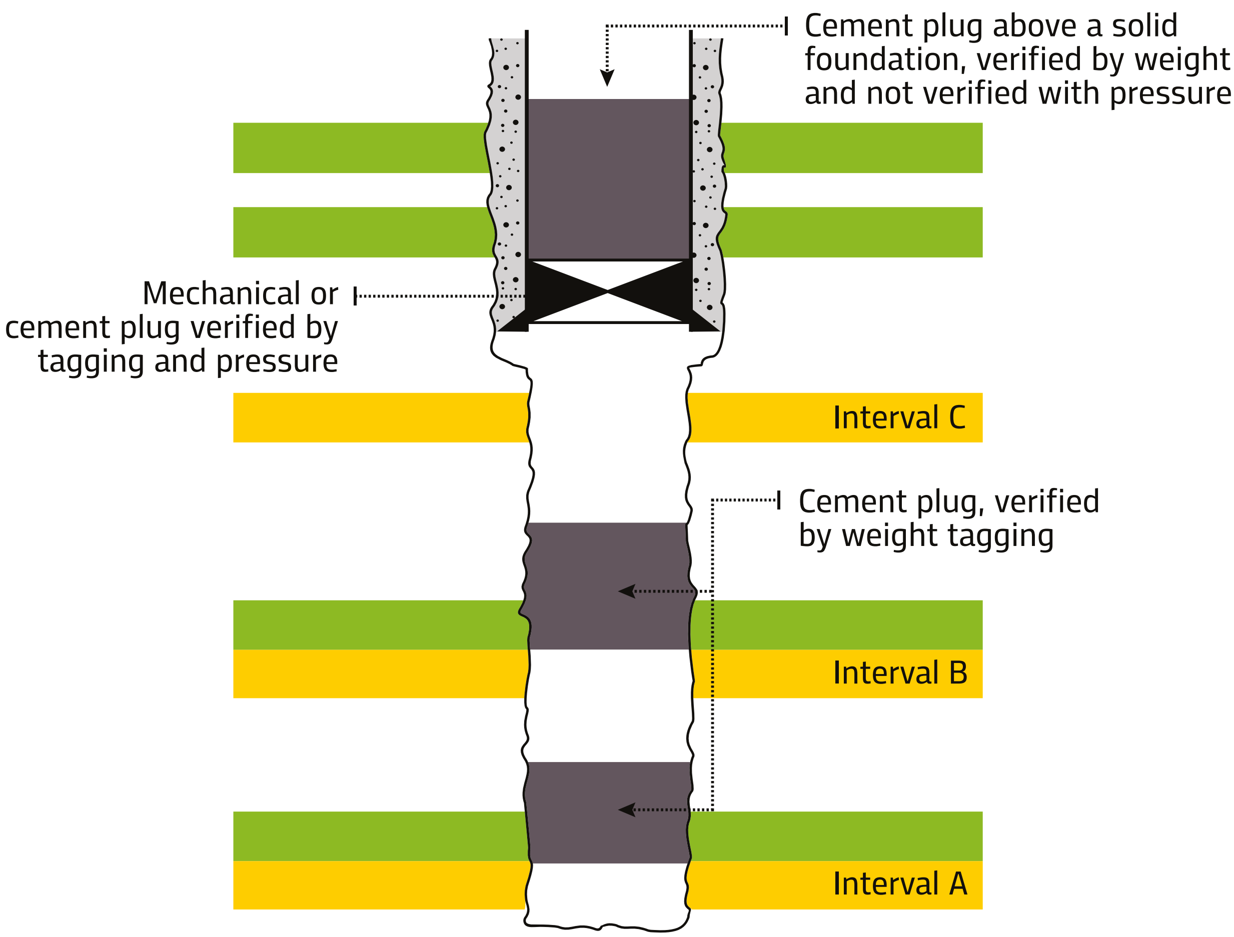
» Installed in a cased well;

» Positioned above an element (or set of elements) whose verification demonstrated sealing ability, with a valid result (see item 6, 1st paragraph);

» Theoretical volume to pressurize against the lower barrier and theoretical volume to pressurize against the upper barrier shows no relevant difference that would enable a volumetric inference.

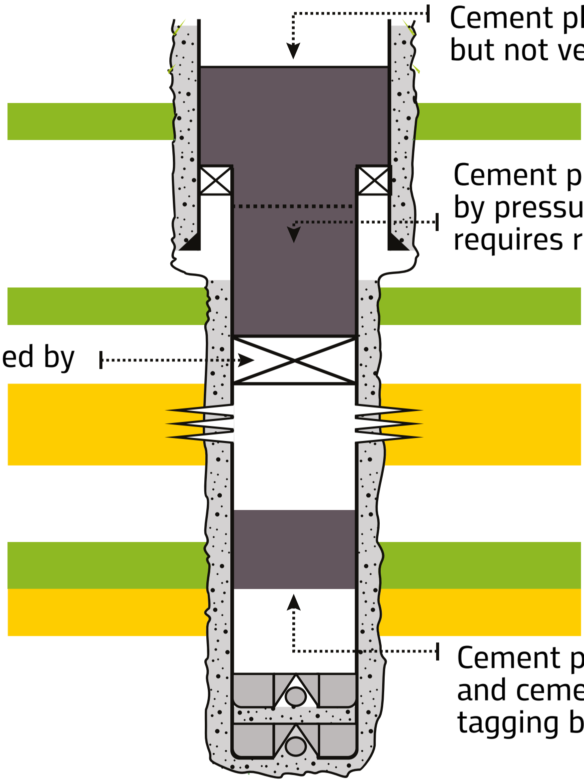
In other cases, even if inconclusive, a seal verification must be performed to mitigate the risk of failure of the seal of both elements (or set of elements).

Figure 37 – Examples of cement plug verification in open hole



Source: Prepared by the Authors.

Figure 38 – Examples of cement plug verification in open hole



Source: Prepared by the Authors.

If more than one verification method of the position or seal is applied, it should be considered that the data acquired by the different methods, when technically valid, are complementary and should be considered jointly for the definition of the WB element integrity status.

When the verification of an WB element is planned, the possibility of isolation failure of the element caused by stresses from the operation and its potential consequences, such as formation fracturing or formation fluids inflow induction, must be assessed. Formation fracturing can cause the communication of different reservoirs with different pressure levels, while testing in the direction of the flow can result in the inflow of fluids from the formation into the well and the communication of reservoirs containing hydrocarbons located at deeper intervals. The operator should consider these risks associated with the verification process so as not to apply unnecessarily excessive parameters.

6.1 Test and confirmation by pressure

These sealing verification methods are somewhat similar, but their particularities must be observed by definition:

a) Test: Verification of an WB element by applying a pressure test in the flow direction, considering differential pressure equal to or greater than the maximum expected pressure;

b) Confirmation: Verification of an WB element through evaluation of data collected during and/or after its installation.

According to the definition of test, it is crucial to identify the direction of the flow that would be immediately established in case of an WB element failure.

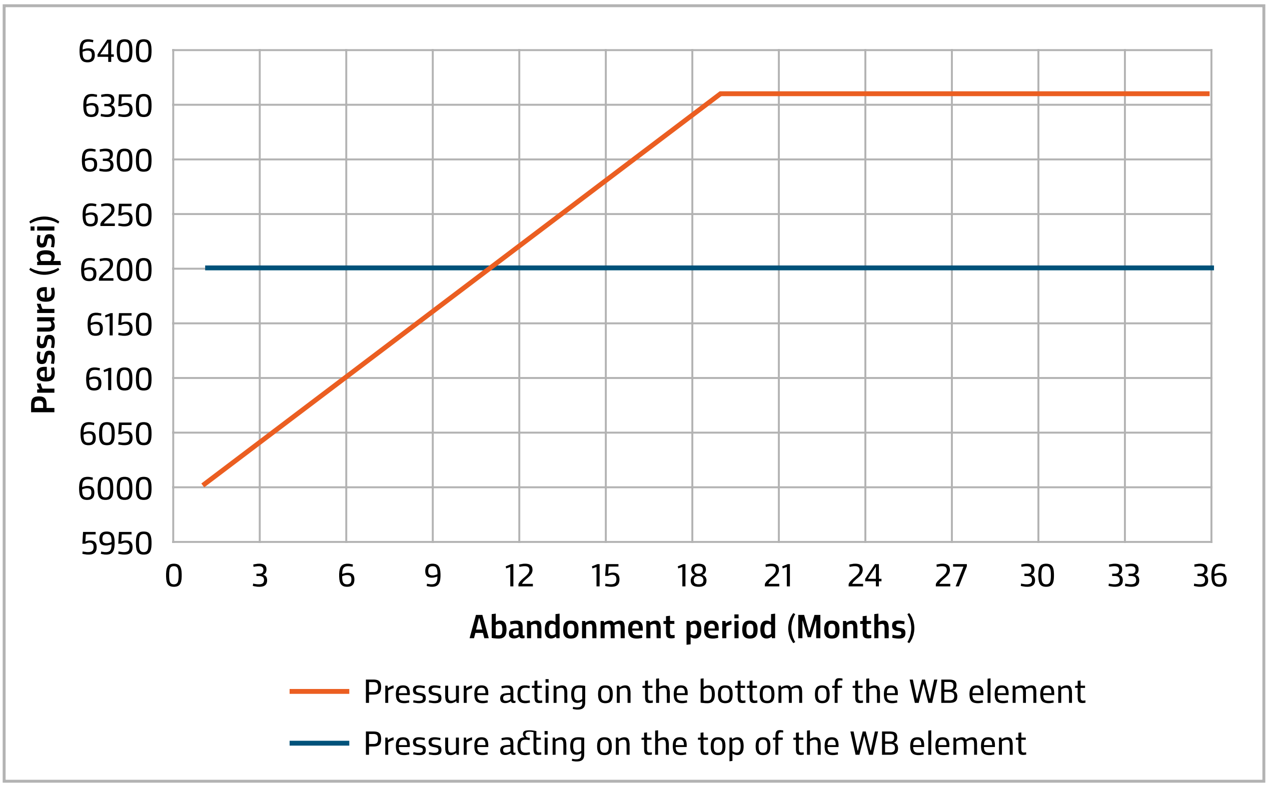
In interventions for temporary or permanent abandonment purposes, the WB elements are usually installed after killing the well and they remain exposed to a downwards pressure differential during the abandonment period. Thus, to be considered as tested, they must be exposed to a downward pressure differential greater than or equal to the maximum expected pressure differential during the abandonment period.

In cases where, for instance, WB elements are installed without well killing or the fluid hydrostatics above the elements are reduced, may cause the WB elements, during the entire abandonment period, to be exposed to upward pressure differentials. In these cases, for the element to be considered as tested, it must receive an upward pressure differential with a value equal to or greater than the maximum expected pressure differential during the abandonment period.

In certain scenarios, it is possible that during the abandonment period a change in the direction of the pressure differential to which the WB element is exposed occurs, caused by effects such as: change in the pressure of the interval with flow potential, or change in the hydrostatic fluid pressure profile above the WB element.

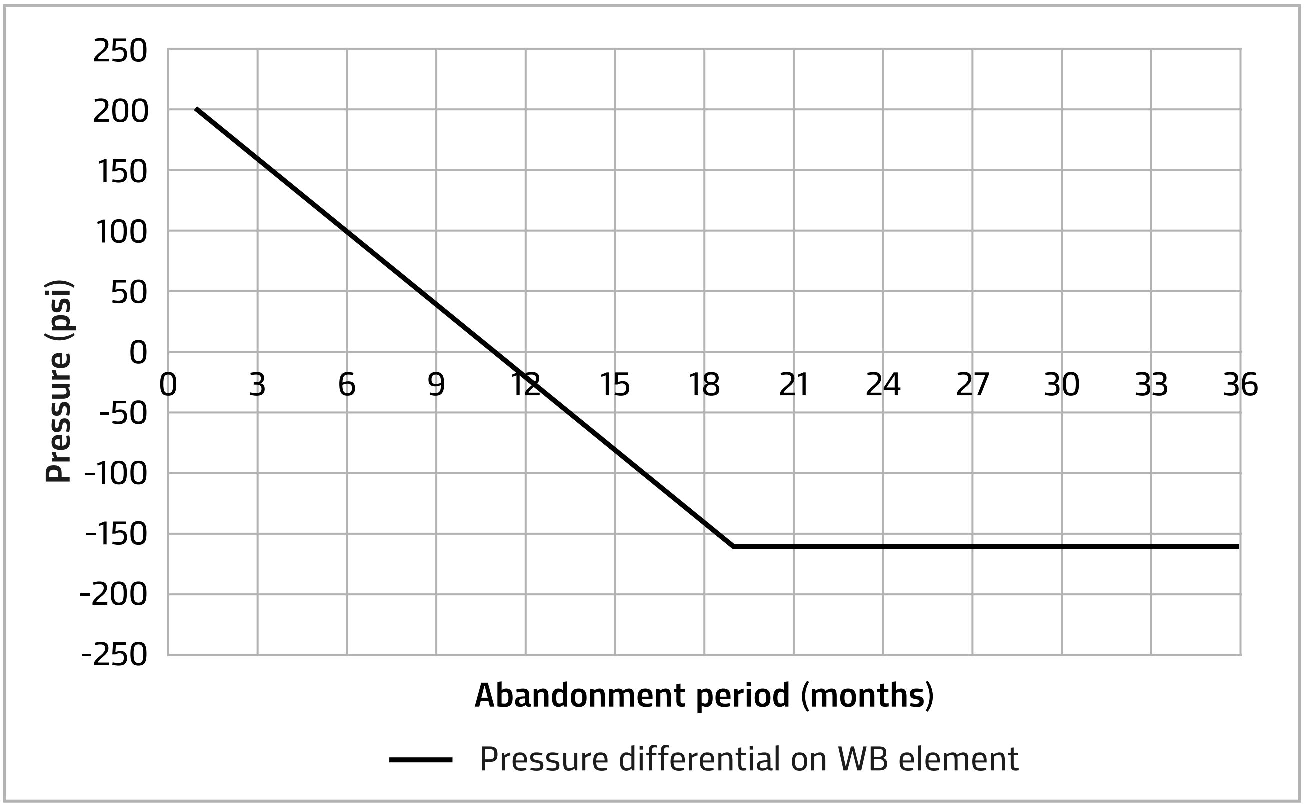
Figures 39 and 40 illustrate this possibility showing that the expected initial pressure differential over the WB element is 200 psi (downwards), but it is expected that during the temporary abandonment period, this differential will continuously change until stabilizing at 160 psi (upwards) due to, for instance, repressurization of the interval with flow potential.

Figure 39 – Example of pressures acting on the top and bottom of the WB element during the abandonment period



Source: Prepared by the Authors.

Figure 40 – Example of pressure differentials acting on the WB element during the abandonment period



Source: Prepared by the Authors.

In this scenario, for the WB element verification to be classified as test, the maximum pressure differential in both directions must be identified, and the verification performed must expose the WB element to both conditions. In this way, the element will have its sealing ability evaluated, considering the most severe loadings expected for the abandonment period, and will then be considered as tested.

In the examples in Figures 39 and 40, for testing the WB element, it should be exposed at least to a 200 psi differential in the downward direction and a 160 psi differential in the upward direction. If verification is performed in only a single direction or with a pressure differential lower than given above, the WB element would be considered as confirmed.

For sealing verifications, by confirmation, which require the application of pressure differential and no detailed information is provided in the EAC Table of the element, it is recommended that the highest pressure among the values below is applied, according to the verification direction adopted by the operator, not to exceeding the limit set on item iv:

i. (Downwards) 500 psi above the leak off test (LOT) pressure, or injection (at a known leak point, perforated section or analogous) below the element under verification;

ii. (Upwards) 300 psi pressure differential on the element;

iii. (Both directions) the pressure differential required for test;

iv. (Both directions) Pressure limit of exposed casings and other exposed equipment or elements.

The operator must record the values considered in its design for pressures acting at the top and bottom of the WB elements that are verified by test.

6.2 Acceptance criteria for WB elements

The acceptance criteria for all WB elements adopted in a temporary or permanent WB should be made explicit. In these guidelines it is recommended to adopt the acceptance criteria, consisting of Design/Construction/Selection, Verification and Applicable Abandonment Type, described in the following Tables. The adoption of acceptance criteria and/or verification methods other than those contemplated in these Tables is possible through a risk-based approach.

Unless otherwise provided in the respective Acceptance Criteria Table, the elements contemplated in this Good Practice Notebook do not, by themselves, require specific periodic monitoring, and may be applied for periods of Monitored Temporary Abandonment or Unmonitored Temporary Abandonment. In the case of Monitored Temporary Abandonment, the frequency and scope established in the E&P Good Practices Notebook - Guidelines for Monitoring of Wells in Temporary Abandonment must be followed.

In case any WB element is not found in the existing element acceptance tables, a new table can be created for this specific element, with its corresponding acceptance criteria.

Chart 1 – Summary of WB Element Verification Methods

		Position				Effectiveness/Tightness				
WB Element	Table	Confirmation by tagging	Confirmation by Operational Parameters	Confirmation by Logging	Confirmation by Other Methods	Confirmation by Presssure	Test	Confirmation by Operational Parameters	Confirmation by Logging	Confirmation by Other Methods
Non-natural flow	Table 1	Not applicable				X	X			X
Casing	Table 2		X	X	X	X	X		X	
Cement plug	Table 3	X	X		X	X	X	X	X	
Alternative barrier material plug	Table 4	X	X		X	X	X	X	X	
Annulus cement	Table 5		X	X	X	X	X	X	X	
Alternative material in annulus	Table 6		X	X	X	X	X	X	X	
Shoe track	Table 7	X	X	X	X	X	X	X	X	
Sealing formation (caprock)	Table 8		X	X	X	X	X		X	X
Creeping formation (unqualified)	Table 9		X	X		X	X		X	
Creeping formation (qualified)	Table 9			X	X	X	X		X	
Production/injection tubing	Table 10		X	X	X	X	X		X	
Production/injection tubing hanger	Table 11		X	X	X	X	X		X	
Production/injection tubing mechanical plug	Table 12	X	X	X	X	X	X		X	
Production/injection tubing components	Table 13		X	X	X	X	X		X	
Liner packer/Tie-back packer	Table 14	X	X	X	X	X	X		X	
Production packer	Table 15	X	X	X	X	X	X		X	
Metal-elastomer Mechanical Annulus Barrier (MAB)	Table 16	X	X	X	X	X	X	X	X	
Double Seal Valve (DSV)	Table 17		X		X	X	X			X
Formation isolation valve (FIV)	Table 18	X	X	X	X	X	X		X	
Wellhead annulus access valve	Table 19				X	X	X			
Subsea Safety Device (SSSD)	Table 20	X	X	X	X	X	X		X	
Annulus safety valve	Table 21		X	X	X	X	X		X	
Retainer valve (Standing valve)	Table 22	X	X	X	X	X	X		X	
Permanent bridge plug, Retrievable bridge plug, cement retainer and abandonment packer	Table 23	X	X	X	X	X	X		X	
Wellhead	Table 24		X	X	X	X	X		X	
Production Adapter Base (PAB)	Table 25		X	X	X	X	X		X	
Completion Adapter Base (CAB)	Table 26		X	X	X	X	X		X	
Wet Christmas tree (WXT)	Table 27		X	X	X	X	X		X	
Dry Christmas tree (DXT)	Table 28		X		X	X	X		X	
Surface isolation valve	Table 29		X		X	X	X		X	
Fluid	Table 30		X	X	X	X	X		X	X
PWC (Perforate, Wash and Cement)	Table 31		X	X	X	X	X	X	X	

Source: Prepared by the Authors.

Table 1 – Non-natural flow

Characteristics	Acceptance Criteria
I. Description	Insufficient reservoir pressure to lift formation fluids and sustain continuous flow to the surface or to the seabed.
II. Functions	Formation fluid exerting hydrostatic pressure on the well that will prevent unintentional continuous flow of fluid from the formation to the external environment.
III. Project/Selection/Construction	1. The well should be analyzed regarding: a) In wet completions, if disconnected from the SPU: status of no-natural flow to the seabed; b) In wet completions, if connected to the SPU: status of no-natural flow to the seabed and surface; **Note:** the analysis to the surface can be disregarded if action(s) is (are) taken to provide the potential flow paths from the WXT with the exposure to seawater hydrostatic pressure (Example of action: keep the swabs of the vertical WXT open on override); c) Onshore or dry completion: status of no-natural flow to the surface. 2. Non-natural flow should be assessed disregarding any artificial lift method. 3. Non-natural flow assessment must consider expected (foreseen) changes to the reservoir characteristics over the abandonment period, including effects of well injection or other recovery methods.
IV. Verification	1. **Positioning:** not applicable 2. **Effectiveness:** must be verified by one of the following methods: a) Test: Absence of natural flow during the production phase, observing the need to maintain parameters that affect well flow condition (for instance: formation static pressure, formation fluid composition) during the abandonment period; b) Pressure confirmation: verification of the static formation pressure, inferred by surface sensors, Christmas tree or in the well, (for instance, PDG) with closed in well; c) Confirmation by other means: performance of flow analyses and modeling, considering information and characteristics of the field wells. 3. **Remarks:** Status of no-natural flow must be verified periodically.
V. Applicable Abandonment Type	Permanent – N/A Temporary – Yes

Source: Prepared by the Authors.

Table 2 – Casing

Characteristics	Acceptance Criteria
I. Description	Casing/Liner tubulars.
II. Functions	Provide physical isolation that prevents the flow of formation fluid or fluid injection between the inside of the tubular and its annulus.
III. Project/Selection/Construction	1. The tubulars, including their connections, shall be designed to withstand the expected internal pressure, buckling pressure, tensile/compression and triaxial loads during the abandonment period. 2. Minimum safety factors for the design must be defined for each type of stress, taking into account the effects of temperature, corrosion and project wear. 3. The casing/liner design must be based on some kind of resistance model, which can be deterministic or probabilistic. 4. The casing/liner subject to be exposed to a hydrocarbon interval must have appropriate connections for the expected loads and fluid types. The exception is surface casing that is only exposed or could potentially be exposed to shallow gas with normal gradient.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the depth at which tubulars were installed; b) Confirmation by other means: by means of records containing information of the intervention where the element was installed, informing element depths; c) Confirmation by logging: interpretation of logs that allow presumption of the positioning of the element installed during a previous intervention, based on typical element characteristics: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness: must be verified by one of the following methods:** a) Test (preferable method); b) Confirmation by pressure; c) Confirmation by logging which enables presumption of the sealing tightness of the tubulars, using methods such as acoustic or flow logs. 3. **Remarks:** a) Tightness can be verified while the cement slurry is still fluid (after top plug landing on the floating collar) or after cement setting. Verification should not be executed during the cement slurry setting; b) For permanent abandonment only, the casing section used to compose a permanent WB has no objective verification criteria, since are the cemented intervals (interior of the well and annuli) that must provide the WB seal and integrity.
V. Applicable Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 3 – Cement plug

Characteristics	Acceptance Criteria
I. Description	Cement slurry that solidifies and hydraulically isolates the interior of the well.
II. Functions	Prevent fluid flow from the formation between distinct formation intervals within the well and/or to the surface/seabed.
III. Project/Selection/Construction	1. A cementing project must be prepared for each cement plug to be installed. 2. The cementing project should be verified by qualified personnel (own or outsourced) in case of critical cementing operations, scenarios in HPHT conditions, and complex cement slurry mixes. 3. The cement slurry formulation should be laboratory tested under representative well conditions with samples of solid and liquid products from the location. The test should report the cement thickening time and compressive strength. The test results should be compatible with the duration and purpose of the cementing job. 4. Cement plugs must be designed to provide long term isolation under estimated static and dynamic conditions for the anticipated loadings in the abandonment period. 5. The plug must be designed for the highest expected pressure differential and downhole temperature for the abandonment period, including installation and verification loadings. 6. A minimum volume of cement slurry should be defined to ensure that homogeneous slurry is placed in the well, considering all possible slurry contaminations since its mixture to its placement in the well. 7. The minimum length of the cement plug in open or cased well must be 30 m for 1 (one) WB element, with provisions of items 4.3.2 and 4.3.2.1. 8. The minimum length of the cement plug, to be a combined WB element, is twice the respective length mentioned in item 7 above.
IV. Verification	1. **Position:** should be verified according to its location and scenario: a) Open hole: should be verified by one of the following methods: – Confirmation by tagging application, using the work/drill tubing; – Confirmation by other means: Presumption of its position, based on interpretation of acoustic pulses emitted to the well and reflected by the element. b) Cased hole: should be verified by one of the following methods: – Confirmation by tagging application, using the work/drill tubing, coiled tubing or slickline/wireline; – Confirmation by other means: positioning presumption based on the correlation between the volume of fluid used for pressurization against the element and the theoretical fluid volume for this pressurization or position presumption based on the interpretation of acoustic pulses emitted into the well and reflected by the element. c) Open or cased hole, exclusively for top hole drilling abandonment: should be verified by one of the following methods: – Confirmation by tagging application, using the work/drill tubing; – Confirmation by operational parameters: control of slurry density, pumping volumes and displacement. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging that enables casing sealing tightness presumption, using methods such as acoustic or flow logs; d) Confirmation by operational parameters (for top hole drilling abandonment): control of slurry density, pumping volumes and displacement etc. 3. **Remarks:** a) For sealing tightness verification, by means of confirmation, which require the application of pressure differentials, the highest pressure among the values below must be applied, in accordance with the adopted verification direction, with the limit of item vi not be exceeded: i. (Downwards) 500 psi above absorption pressure (LOT), measured or estimated, or shoe track injection; ii. (Downwards) 500 psi above absorption pressure (LOT), measured or estimated, or injection at a known leakage point; iii. (Downwards) 500 psi above absorption pressure (LOT), measured or estimated, or injection of the perforated interval; iv. (Upwards) a pressure differential of 300 psi; v. (Downwards & upwards) the required test pressure differential; vi. (Downwards & upwards) maximum verification pressures of exposed liners and remaining exposed equipment/elements. b) In case of consecutive plugs, if the bottom of the next plug is seated immediately above the top of the previous plug, verification can be performed after placing the shallowest plug;

Table 3 – Cement plug (Continued)

Characteristics	Acceptance Criteria
IV. Verification	c) Verification by tagging may be dispensed in exceptional cases and after a risk analysis, considering aspects such as: existence of a solid base for the plug, type of material used, etc.; d) Verification with pressure application to a cement plug may be inconclusive and therefore not necessary, provided that the cement plug meets one of the following conditions: i. Seated in cased hole, above a mechanical, cement plug or cemented shoe track verified by pressure, and the result is valid (see item 6, 1st paragraph); ii. Seated in cased hole, with the casing section below the cement plug not perforated or without any known leak point; iii. Seated in open hole.
V. Applicable Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 4 – Alternative barrier material plug

Characteristics	Acceptance Criteria
I. Description	Alternative slurry material that solidifies and hydraulically isolates the well. These alternative materials are resins or binders other than Portland cement.
II. Functions	Prevent fluid flow from the formation between distinct formation intervals within the well and/or to the surface/seabed.
III. Project/Selection/Construction	1. A cementing project must be prepared for each plug to be installed. 2. The cementing project must be verified by qualified personnel (own or outsourced). 3. The slurry formulation should be laboratory tested under representative well conditions with samples of solid and liquid products from the location. The test should report the cement thickening time and time to develop compressive strength. 4. The plugs must be designed to provide long-term isolation, under estimated static and dynamic conditions and anticipated loadings in the abandonment period. 5. The plug must be designed for the highest expected pressure differential and downhole temperature in the abandonment period, including its installation and verification loadings. 6. A minimum volume of slurry should be defined to ensure that homogeneous slurry is seated in the well, considering all possible slurry contaminations since its mixture to its placement in the well. 7. The minimum length of the cement plug in open or cased hole must be 30 m for 1 (one) WB element, with provisions of items 4.3.2 & 4.3.2.1. 8. The minimum length of the cement plug, to be a combined WB element, is twice the respective length mentioned in item 7 above.
IV. Verification	1. **Position:** should be verified according to its location and scenario: a) Open hole: should be verified by one of the following methods: – Confirmation by tagging application, using the work/drill string; – Confirmation by other means: presumption of its position, based on interpretation of acoustic pulses emitted to the well and reflected by the element. b) Cased hole: should be verified by one of the following methods: – Confirmation by tagging application, using the work/drill string, coiled tubing or wireline/cable; – Confirmation by other means: position presumption based on the correlation between the volume of fluid used for pressurization against the element and the theoretical fluid volume for this pressurization or position presumption, based on the interpretation of acoustic pulses emitted into the well and reflected by the element. c) Open or cased hole, only for top hole drilling abandonment: should be verified by one of the following methods: – Confirmation by tagging application, using the work/drill string; – Confirmation by operational parameters: control of slurry density, pumping volumes and displacement. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging that allows to infer the sealing tightness of the alternative plug material, using methods such as acoustic or flow logs; d) Confirmation by operational parameters (exclusively for abandonment in top hole drilling): control of slurry density, pumping volumes and displacement. 3. **Remarks:** a) For sealing tightness verification, by means of confirmation, which require the application of pressure differentials, the highest pressure among the values below must be applied, in accordance with the adopted verification direction, with the limit of item vi not be exceeded: i. (Downwards) 500 psi above absorption pressure (LOT), measured or estimated, or shoe track injection; ii. (Downwards) 500 psi above absorption pressure (LOT), measured or estimated, or injection at a known leakage point; iii. (Downwards) 500 psi above absorption pressure (LOT), measured or estimated, or injection of the perforated interval; iv. (Upwards) a pressure differential of 300 psi; v. (Downwards & upwards) the required test pressure differential; vi. (Downwards & upwards) maximum verification pressures of exposed liners and remaining exposed equipment/elements. b) In case of consecutive plugs, if the bottom of the next plug is seated immediately above the top of the previous plug, verification can be performed after placing the shallowest plug.

Table 4 – Alternative barrier material plug (Continued)

Characteristics	Acceptance Criteria
IV. Verification	c) Verification by tagging may be dispensed in exceptional cases and after a risk analysis, considering aspects such as: existence of a solid base for the plug, type of material used, etc.; d) Verification with pressure application to a cement plug may be inconclusive and therefore not necessary, provided that the cement plug meets one of the following conditions: i. Seated in cased hole, above a mechanical, cement plug or cemented shoe track verified by pressure, and the result is valid (see item 6, 1st paragraph); ii. Seated in cased hole, with the liner section below the cement plug not perforated or without any known leak point; iii. Seated in open hole.
V. Applicable Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 5 – Annulus cement

Characteristics	Acceptance Criteria
I. Description	Hardened cement slurry located in the annuli between concentric metal tubulars (casing, production, injection tubing, work string, among others) or between metal tubulars and the formation wall.
II. Functions	Provide hydraulic well isolation in concentric metallic tubulars annuli and between tubulars and the formation wall, preventing fluid flow from the formation by avoiding pressure transmission from the top or bottom of the cemented annular section. In addition, in conductor and surface casings, the cemented annulus has the function of providing structural well integrity.
III. Project/Construction/Selection	1. Planning each primary casing/liner cementing job must cover at least the following items: i) Isolation of the current shoe, if applicable; ii) Obtaining the required hydraulic isolations, respecting well geometry and the formations involved; iii) Analysis of the casing eccentricity to obtain isolation over the entire length required; iv) Use of cement spacers, chemical washers, and mechanical spacers should be carefully evaluated in order to meet the objectives of chemical and rheological compatibility, wettability reversal, and required fluid removal efficiency in the annulus; v) Analysis of the effects of the hydrostatic pressure differential between the inside and outside of the casing/liner, ECD during cementing and the loss of hydrostatic pressure prior to cement slurry placement; vi) Use of required pumping volumes and speed for spacers and cement slurries to reduce cement slurry contamination from well fluids during its placement in the annulus; vii) Loss event during cementing and required mitigations. 2. The cementing program should be verified by the well project manager for critical cementing operations, scenarios under HPHT conditions, and complex slurry/foamed slurry mixes. 3. The cement slurry formulation should be laboratory tested under representative well conditions with solid and liquid product samples, also representative of the location. The test should report the hardening time and compressive strength of the cement. The test results should be compatible with the duration and purpose of the cementing job. **Note:** Planning of the remaining cementing jobs in structural annuli (THD) should cover the same topics as above, except those not applicable to the operation scenario. 4. The annulus cement length must: a) Allow for future well use (production, deviation, recompletion and abandonment, among other operations); b) Conductor and surface casings: their definition must be based on the structural integrity requirements to meet the loading conditions arising from wellhead equipment and operations to be performed; c) Allow to compose the planned WB of the intervals to be isolated. 5. The minimum length of cement in annulus should be 30 m for 1 (one) WB element whose sealing tightness was test verified, Confirmation by pressure application or logging, and 60 m for 1 (one) WB element whose sealing tightness is verified by confirmation of operational parameters, with observance of the provisions of 4.3.2 and 4.3.2.1. 6. The minimum length of the cement in annulus, in order to be a combined WB element, is twice the respective length mentioned in 5.
IV. Verification	1. **Position:** the length and position of the cement in annulus must be verified by one of the following methods: a) Confirmation by logging: using tools/methods selected based on their capacity to provide data for presumption of the cement position. The logs must be analyzed and documented; b) Confirmation by operational parameters: records of the cementing operation that allow presumption of the position of the cement in annulus, such as, for instance, expected pressure growth at the end of the displacement, control of pumped and returned volumes, and analysis of the impacts of abnormal occurrences (loss, inflow, unplanned pumping stops, unplanned fluid return, among others). This assessment must be documented; c) Confirmation by other means: records containing information from the construction stage, informing element depths. 2. **Tightness:** must be verified by one of the following methods: a) Confirmation by logging: using tools/methods selected based on their capacity to provide data for presumption of cement position logs must be analyzed and the analysis documented (presumption of hydraulic isolation), using methods such as (sonic or ultrasonic), acoustic, flow, or saturation logs. The logs should be analyzed and the analysis documented; b) Confirmation by operational parameters: records of the cementing operation attesting the normality of the operation, such as, for instance, expected pressure rise at the end of the displacement, control of the pumped and returned volumes indicating no loss of circulation or inflow, slurries and chemical washer mixed to the design weight, plug placing on collar bottom, seal confirmed by the floating valves, pressure test indicating tightness of the liner on plug, etc.; c) Test: by application of pressure differential on the cement sheath; d) Confirmation by pressure application: by establishing a pressure differential on the cement sheath. 3. **Remarks:** a) No pressurization of the tubulars should be carried out during the cement slurry gelling process; only while still fluid or after the cement acquired adequate compressive strength; b) In cases of loss of circulation, it must be documented that the pertinent interval is above the planned top of the cement. An acceptable documentation example is an operational comparison of a correlation well in which a similar loss occurred and had sufficient cement length verified by log; c) Methods for handling incomplete records of cementing operations should be employed to perform cement in annulus verification by operational parameters, in addition to existing information. Retrograde analysis and computer simulations can be employed.
V. Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 6 – Alternative material in annulus

Characteristics	Acceptance Criteria
I. Description	Alternative slurry material for cementing the annuli between concentric metal tubulars (casing, production, injection, work string, among others) or between metal tubulars and the formation wall. These alternative materials are resins or other materials with cementitious properties other than Portland cement.
II. Functions	Provide hydraulic isolation along the wellbore in concentric metal tubular annuli and between metal tubulars and the formation wall, preventing fluid flow from the formation, preventing pressure transmission from the top or bottom of the annular section with alternative material.
III. Project/Selection/Construction	1. Planning each operation with alternative material must follow specific procedures and standards as well as manufacturer's guidance. 2. The tubulars' isolation program should consider conditions during the abandonment period, such as higher pressure and temperature differentials, including HPHT scenarios, installation and verification loadings. 3. The operation program should be verified by the well design manager for operations with alternative material. 4. The alternative cement slurry formulation should be laboratory tested under representative well conditions with samples of solid and liquid products from the location. The test should report the cement hardening time and compressive strength. The test results should be compatible with the duration and purpose of the cementing job. 5. The alternative cement slurry mix should: a) Allow for future well use (production, deviation, recompletion and abandonment, among other operations); b) Allow to compose the planned WB of the intervals to be isolated. 6. The minimum length of alternative cement in annulus should be 30 m for 1 (one) WB element whose sealing tightness is test verified, confirmation by pressure application or profiling, and of 60 m for 1 (one) WB element whose sealing tightness is verified by confirmation of operational parameters, with observance of the provisions of items 4.3.2 and 4.3.2.1. 7. The minimum length of the alternative material in annulus, in order to be a combined WB element, is twice the respective length mentioned in 5.
IV. Verification	1. **Position:** the length and position of the alternative cement in annulus must be verified by one of the following methods: a) Confirmation by logging: profiling tools/methods shall be selected based on the ability to provide data for presumption of the positioning of the alternative material in the annulus. Profiles shall be analyzed and the analysis documented; profiling tools/methods shall be selected based on the ability to provide data for presumption of the position of the cement. Profiles shall be analyzed and the analysis documented; b) Confirmation by operational parameters: records of the cementing operation that allow presumption of the position of the cement in annulus, such as, for instance, expected pressure growth at the end of the displacement, control of pumped and returned volumes, and analysis of the impacts of abnormal occurrences (loss, inflow, unplanned pumping stops, unplanned fluid return, among others). This assessment must be documented; c) Confirmation by other means: records containing information from the construction stage, informing element depths. 2. **Tightness:** must be verified by one of the following methods: a) Confirmation by logging: using tools/methods selected based on their capacity to provide data for presumption of cement position logs must be analyzed and the analysis documented (presumption of hydraulic isolation), using methods such as (sonic or ultrasonic), acoustic, flow, or saturation logs. The logs should be analyzed and the analysis documented; b) Confirmation by operational parameters: records of the cementing operation attesting the normality of the operation, such as, for instance, expected pressure rise at the end of the displacement, control of the pumped and returned volumes indicating no loss of circulation or inflow, slurries and chemical washer mixed to the design weight, plug placing on collar bottom, seal confirmed by the floating valves, pressure test indicating sealing tightness of the liner on plug, etc.; c) Test: by establishing a pressure differential on the alternative material sheath; d) Confirmation by pressure application: by establishing a pressure differential on the alternative cement sheath. 3. **Remarks:** a) In cases of loss of circulation, it must be documented that the interval with loss is above the planned top of the alternate material slurry. An acceptable example of documentation is an operational comparison of a correlation well in which a similar loss occurred and had sufficient length verified by log.
V. Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 7 – Shoe track

Characteristics	Acceptance Criteria
I. Description	A casing section immediately above the shoe filled with cement.
II. Functions	Prevent flow of fluids from the formation to the surface or seabed through the casing.
III. Project/Selection/Construction	1. A program for the primary cementation of the casing must be developed. 2. The cementing project must be verified by qualified personnel (own or outsourced) in case of critical cementing operations, scenarios in HPHT conditions, and complex cement slurry mixes. 3. The cement slurry formulation should be laboratory tested under representative well conditions with samples of solid and liquid products from the location. The test should report the cement hardening time and compressive strength. The test results should be compatible with the duration and purpose of the cementing job. 4. The shoe track cement must be designed to provide long-term isolation under estimated static and dynamic conditions and anticipated loads for the abandonment period. 5. The cemented shoe track must be designed for the highest expected pressure differential and downhole temperature for the abandonment period, including installation and verification loads. 6. The minimum length of the cemented shoe track must be 30 m with observance of the provisions of items 4.3.2 and 4.3.2.1.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by other means: applicable to the casing components, by means of records containing construction stage information, informing element depths; b) Confirmation by operational parameters: applicable to the cement inside the casing, by releasing the bottom and top scraper plugs and tapping the top scraper plug into the floating collar according to the predicted volume, with a difference of up to half of the volume between the collar and shoe being acceptable for plug tapping; c) Confirmation by logging: interpretation of logs that allow presumption of cement positioning based on typical casing characteristics: presence of metallic material, depths of connections, diameter, etc.; d) Confirmation by tagging application, using the work/drill string. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging to infer the sealing tightness of the cemented shoe track, using methods such as acoustic or flow logs; d) Confirmation by operational parameters (for top hole drilling abandonment): control of slurry density, pumping volumes and displacement, functionality of the float valve etc. 3. **Remarks:** a) In case of verification the cement position by operational parameters, no verification of top plug tapping is acceptable, provided the calculated cement length (or confirmed by weight) inside the casing is at least 30 m; b) A cement sample can be collected at the surface to be used as an indicator of the compressive strength of the cement. The surface sample does not replicate the pressure and temperature conditions in the well and therefore there may be significant differences in cement quality at the surface and down the well; c) In sealing tightness verifications, by means of confirmation, that demand pressure differential application, the greatest pressure among the values below must be applied, according to the adopted verification direction, and must not exceed the limits of item iv: i. (Downwards) 500 psi above absorption pressure (LOT), measured or estimated, or shoe track injection; ii. (Upwards) pressure differential of 300 psi; iii. (Downwards & upwards) the required pressure differential for the test; iv. Verification pressure limit of exposed casings and remaining exposed equipment/elements. d) No pressurization of the casing should be carried out during the cement slurry gelling process; only while fluid or after the cement acquired adequate compressive strength; e) For onshore wells, verification of the static level of the abandonment fluid in the well is acceptable for cemented shoe track verification in the flow direction; f) The consideration of cemented shoe tracks as permanent WB elements has its application limited to permanent abandonment scenarios of dry wells or top hole drilling.
V. Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 8 – Sealing formation (caprock)

Characteristics	Acceptance Criteria
I. Description	Drilled formation, located adjacent to the isolation material in the annulus of the casing/liner or in an open hole.
II. Functions	Provide a hydraulic and permanent isolation preventing flow from inside the well to the surface, seabed or other well interval.
III. Project/Selection/Construction	1. A sealing formation (caprock) must meet the following criteria: a) Be impermeable without flow potential; b) Be distant from fractured zones or faults that could lead to cross flow or injection into other intervals; c) The competence of the formation must be sufficient to withstand the maximum pressure expected for the entire abandonment period; d) Must not be affected by reservoir pressure changes over time; e) Must bond to the isolation material positioned inside the well or casing/liner annulus; f) If there is formation creep with direct closure of the annulus, the element must be designed according to the Table 9 (Formation creep).
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by logging: application of methods such as resistivity, gamma ray, sonic, density and porosity that allow inferring the identification of the formation; b) Confirmation by operational parameters: parameters related to the well depth that allow inferring the identification of the formation through indirect data such as perforation slowdown rate, associated with the geological prediction of the area; c) Confirmation by other means: parameters related to the depth of the well that allows inferring the identification of the formation through direct data (analysis of returned cuttings) or indirect data (such as correlation with the calibrated geological model. 2. **Tightness:** must be verified by one of the following methods: a) Test; b) Confirmation by pressure application; c) Confirmation by logging: enabling presumption of the sealing competence of the sealing formation (caprock), using methods such as, flow, saturation logs, or those that allow inferring low permeability; d) Confirmation by other means: by analyzing a calibrated geomechanical model of the field. 3. **Remarks:** Typical verifications such as formation integrity test (FIT), dynamic formation integrity test (DFIT), leak off test (LOT) and extended leak off test (XLOT) can be classified as valid tests or confirmation by pressure application, depending on the pressure differential applied and the direction and pressure differential to which the sealing formation (caprock) will be subject during the abandonment period.
V. Applicable Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 9 – Creeping formation

Characteristics	Acceptance Criteria
I. Description	Formation that deforms plastically on contact with the external area of the casing/liner.
II. Functions	Provide hydraulic and permanent isolation along the annular of the casing/liner to prevent fluid flow from the formation and to resist the pressures applied to its top and bottom.
III. Project/Selection/Construction	1. The minimum total formation interval must be 30 m long unless it is demonstrated in the qualification process that a shorter length is capable of withstanding the maximum expected pressure differential for the abandonment period. 2. The integrity of the formation with creep must be sufficient to withstand the maximum pressure expected for the entire abandonment period. 3. The element must be able to withstand the maximum expected pressure differential for the entire abandonment period.
IV. Verification	The verification requirements are defined according to the qualification stage of the respective formation with creep acting as WB element: **Formation without competence:** 1. **Positioning:** should be verified by one of the following methods: a) Confirmation by logging: two (2) measurements should be made with independent acoustic profiling tools. The measurements obtained from the logs should provide data for the entire section investigated and at least one (1) of the measurements should provide an indication of creep occurrence around the casing. The logs shall be analyzed and the analysis documented. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging: using tools that enable to identify the occurrence of flow during conditions of pressure differentials the formation is exposed to, using methods such as acoustic or flow logs. d) Depending on the geological scenario and field experience, the operator must define the number of wells required for the qualification of a formation creep; e) The basic principle for qualification is that the formation shows lateral continuity and that the verifications performed while under the "unqualified" status meet the acceptance criteria. **Formation competence:** 1. **Positioning:** should be verified by one of the following methods: a) Confirmation by logging: the measurements obtained from the acoustic bonding log must provide data for the entire investigated section indicating compatibility with the expected results, based on what was recorded during the qualification process of the respective formation creep. The logs must be analyzed and the analysis documented; b) Confirmation by other means: geological studies prepared from the formation creep qualification process capable of indicating the expected interval of formation presence in the well. 2. **Tightness:** must be verified by one of the following methods: a) Test; b) Confirmation by pressure application; c) Confirmation by logging: with a tool capable of identifying the occurrence of flow during a condition where the formation is exposed to a pressure differential, such as sound or flow logs, or a tool capable of inferring the bonding of the formation to the liner, can be used. 3. **Remarks:** a) Tightness verification by application of pressure differential is required if the log response is not conclusive or if there is uncertainty related to geological similarity.
V. Applicable Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 10 – Production/injection tubing

Characteristics	Acceptance Criteria
I. Description	The strings comprising tubulars for fluid production/injection.
II. Functions	The purpose of the production string/injection line is to serve as one of the means by which fluids are conveyed to the Christmas tree or injected into the formation.
III. Project/Selection/Construction	1. The parts of the production string/injection line that make up a temporary WB must meet the following requirements: a) The production string/injection line must be designed to provide sealing of the maximum expected pressure differential over the period the well will be abandoned; b) Sealing to the fluids of the pertinent interval isolated by the element; c) The metallurgy of the production string/injection line must be compatible with the temperatures and fluids that will be in contact with the production string/injection line components (as for instance, brine, H_2S and CO_2) during the abandonment period; d) The tubulars must support the loads to which they will be subjected during the abandonment period. 2. Control cables and chemical injection lines can be present in the production string/injection line sections that make up the permanent WB, with observance of the procedures described in 5.11.1.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by other means: records containing information from the construction stage, informing element depths; b) Confirmation by logging: interpretation of logs that allow presumption of positioning based on typical characteristics of the production string/injection line: presence of metallic material, depths of connections, diameter, etc.; c) Confirmation by operational parameters: at installation, by recording the elements and the downhole depth; in subsequent interventions, by analyzing the points where location of the seating logs occurred, (nipples) or diameter variation in flow rate gauging maneuvers. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging enabling presumption of the sealing tightness of the production string/injection line, using methods such as acoustic or flow logs.. 3. **Remarks:** must be verified by one of the following methods: a) For permanent abandonment only, the production string/injection line section used to make up a permanent WB has no objective verification criteria, for being the cemented intervals (inside the well and annulus) that should provide the WB seal and integrity.
V. Applicable Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 11 – Production/injection tubing hanger

Characteristics	Acceptance Criteria
I. Description	The element consists of a body, seals, an anchoring mechanism, line and/or cable passages and bore(s), being interface equipment between the production string/injection line and the Christmas tree.
II. Functions	1. Support the weight of the production string/injection line. 2. Provide isolation between the production/injection bore and the casing/liner annulus. 3. Provide the interface between the well and WCT: production string/injection line x production/injection bore of the WCT, string x casing and the WCT annulus bore. 4. Allow connection to the Christmas tree by the stabs. 5. Allow the installation of a plug for isolation of the production/injection bore and, depending on the constructive characteristics, provide a seat for a plug in the annular bore. 6. Allow locking and unlocking in the CAB, BAP, WCTH or wellhead. 7. Allow testing of the BOP by maneuvering the specific tool for this purpose.
III. Project/Selection/Construction	1. Be compatible with temperatures, internal and external pressures, tension and other stresses generated during intervention operations and abandonment period. 2. The metallurgy of the production string/injection line hanger must be compatible with the temperatures and fluids that it will be in contact with (for instance, brine, H_2S, and CO_2) during the abandonment period. 3. The tubing hanger must withstand the loads it will be subjected to during the abandonment period.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: the anchoring of the tubing hanger must be confirmed with application of tension during the installation operation; b) Confirmation by other means: records containing information from the construction stage, informing element depths; c) Confirmation by logging: interpretation of logs that allow presumption of positioning based on typical characteristics of the production string/injection line: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** the interfaces to other equipment, such as wellhead, BAP, BAC, production string/injection line and downhole access lines should be verified by one of the following methods: a) Test (preferable method); b) Verification with pressure application; c) Confirmation by logging that allows presumption of sealing tightness, using methods such as acoustic or flow logs.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Table 12 – Production/injection tubing mechanical plug

Characteristics	Acceptance Criteria
I. Description	The mechanical plug comprises three (3) main parts: a) Anchor: mechanical element with the function to anchor the mechanical plug inside the production string/injection tubing and promote sealing with the walls of the tubulars or profile where it is seated. It can be seated on specific profiles (nipples) or inside a production pipe (nippleless lock); b) Equalization sub: mechanical element connected to the anchor, with one or more holes to allow pressure equalization above and below the mechanical plug; c) Equalization device: mechanical element that, when seated (or closed), isolates the pressure equalization holes, preventing flow inside the mechanical plug. When unseated (or open), the equalization holes are exposed and allow communication between the pressures above and below the mechanical plug, facilitating subsequent unseating of the anchor. This device can be a rod with external seals (most usual) or a valve.
II. Functions	Prevent flow inside the production string/injection line downwards & upwards (formation vs. external environment and vice-versa).
III. Project/Selection/Construction	1. Locking mechanisms seated on nipples must meet the API 14 L Standards. The design must have validation grade V1 and quality control must meet Q1 grade of this same standard. 2. Locking mechanisms for seating on production string (nippleless) must meet API 11D1 Standard. The design must have validation grade V1, or V0 if there is free gas in the depth of the plug. The quality control must meet the Q1 grade of this same standard. 3. The plug must be designed to support the maximum pressure differential anticipated during the abandonment period. 4. The mechanical plug materials must be able to withstand the temperatures of the medium and the composition of the fluids contained by the plug (for instance, brine, H_2S and CO_2) during the entire abandonment period. 5. It must have a device that allows controlled equalization of the pressures above and below the plug body.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: on installation, the anchorage of the anchor must be verified with the tension recommended by the manufacturer; b) Confirmation by other means: by means of logs containing information from the intervention where the element was installed, informing element depths or positioning presumption based on the interpretation of acoustic pulses emitted into the well and reflected by the element; c) Confirmation by logging: interpretation of logs that allow presumption of positioning of the element installed during a previous intervention, based on typical characteristics of the production string/injection line and of the mechanical plug: presence of metallic material, depths of connections, diameter, etc.; d) Confirmation by tagging: using coiled tubing or wireline/cable to confirm positioning of the element installed in the previous intervention. 2. **Tightness: must be verified by one of the following methods:** a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging to infer sealing tightness, using methods such as acoustic or flow logs. 3. **Remarks:** a) Verification by pressure application on a mechanical plug may be inconclusive and therefore dispensed with, provided the mechanical plug is positioned above an WB element (or set of elements) whose tightness has been verified, with valid result (see item 6, 1st paragraph).
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 13 – Production/injection tubing components

Characteristics	Acceptance Criteria
I. Description	Any accessory or equipment integrated into the production string/injection line to perform a specific function during the productive well lifetime (for instance, mandrels, nipples and control lines). **Note:** This Table does not include production tubing (see Table 10) or safety valves (see Tables 17, 18, 20 and 21).
II. Functions	The components of the production string performs various functions during the productive well lifetime, such as, for instance, flow assurance (scale inhibition, paraffin), toxic fluid inhibition (injection of H2S sequestrant), artificial lift (gas lift fittings, subsurface centrifugal pump), pressure and temperature measurements, among others.
III. Project/Selection/Construction	Production string/injection line components that make up a temporary WB must meet the following requirements: a) The components must ensure sealing to the maximum expected pressure differential over the well abandonment period; b) Metallic and non-metallic materials must be compatible with the temperatures and fluids that the production string/injection line components will be in contact with (e.g. brine, H_2S and CO_2) during the abandonment period. Cables and control lines (production string/injection line components) remaining in a permanent WB must follow the provisions of item 5.10.1.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by other means: records with information from the construction stage, informing element seating depths; b) Confirmation by logging: interpretation of logs that allow presumption of positioning based on typical characteristics of the production string/injection line component: presence of metallic material, depths of connections, diameter, linear weight etc.; c) Confirmation by operational parameters: analysis of points where nipples were located or where there was a diameter variation in gauging maneuvers. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging enabling presumption of the tightness of the production string/injection line component, using methods such as acoustic or flow logs. 3. **Remarks:** a) For permanent abandonment only, the section of the production string/injection line component used to make up the permanent WB has no objective verification criteria, for being the cemented intervals (inside the well and annulus) that should provide the WB sealing and integrity.
V. Applicable Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

Table 14 – Liner packer/Tie-back packer

Characteristics	Acceptance Criteria
I. Description	This element consists of a tubular body with an external annular sealing element that is activated during installation.
II. Functions	Its objective is to provide a hydraulic seal in the annular between the previous casing and the liner, preventing flow of formation fluids and preventing transmission of pressures from above or below the element.
III. Project/Selection/Construction	1. Must be qualified and tested according to requirements set forth in recognized standards (as for instance, ISO 14310). 2. Must be designed for maximum stresses and the maximum estimated background temperature during installation and abandonment period.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by other means: records containing information from the construction stage, informing element seating depths; b) Confirmation by tagging application, using the work/drill string; c) Confirmation by logging: interpretation of logs that allow positioning presumption based on typical liner characteristics: presence of metallic material, depths of connections, diameter, etc.; d) Confirmation by operational parameters: at installation, by recording the depth at which the seating operation takes place. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation with pressure application; c) Confirmation by logging enabling presumption of the sealing tightness of the packer/tie-backpacker liner, using methods such as acoustic or flow logs. **3. Remarks:** a) Tightness can be verified while the cement slurry is still flowing or after the cement hardened. Verification should not be performed during the gelling of the cement slurry. b) In tightness verifications, by means of confirmation, that demand the application of a pressure differential, the highest pressure among the values below must be applied, according to the adopted verification direction, without exceeding the limit in item v: i. (Downwards) 500 psi above leak off pressure (LOT) of the weakest exposed formation below the overlap section, measured or estimated, or shoe injection; ii. (Downwards) 500 psi above the injection pressure at the leakage point of the previous liner; iii. (Upwards) pressure differential of 300 psi; iv. (Downwards & upwards) the required pressure differential for the test; Verification pressure limit of exposed liners and remaining exposed equipment/elements.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 15 – Production packer

Characteristics	Acceptance Criteria
I. Description	This equipment consists of a casing/liner anchoring device and an annular sealing element that is activated during installation.
II. Functions	Prevent flow through the annulus between tubing and production casing, downwards & upwards (formation vs. annular space and vice-versa).
III. Project/Selection/Construction	1. The packer must guarantee sealing to the maximum expected pressure differential over the abandonment period. 2. Metallic and non-metallic materials must be compatible with the temperatures and fluids that will be in contact with the packer (for instance, brine, H_2S and CO_2) during the abandonment period.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the depth at which the seating operation takes place; b) Confirmation by other means: by means of logs containing information from the intervention where the element was installed, informing element depths or positioning presumption based on the interpretation of acoustic pulses emitted into the well and reflected by the element; c) Confirmation by tagging application, using the work/drill string to confirm positioning of the element installed during a previous intervention; d) Confirmation by logging: interpretation of logs that allow presumption of element position installed during a previous intervention, based on typical element characteristics: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging enabling presumption of the tightness of the packer, using methods such as acoustic or flow logs. 3. **Remarks:** a) In tightness verification, by means of confirmation, which require the application of pressure differential, the higher pressure of the values below must be applied, according to the adopted verification direction, with the limit of item v not be exceeded; i. (Downwards) 500 psi above leak off test pressure (LOT) of the weakest formation exposed below the packer; ii. (Downwards) 500 psi above the injection pressure at the leak point or completed interval below the packer; iii. (Upwards) Upward pressure differential of 300 psi; iv. (Downwards & upwards) The required pressure differential for the test; v. Verification pressure limit of exposed casings and remaining exposed equipment/elements. b) Pressure verification of a packer may be inconclusive and therefore dispensed with, provided the packer meets one of the following conditions: i. Seated in cased hole, above of the element (or set of elements) whose sealing tightness was verified, with valid result (see item 6, 1st paragraph); ii. Seated in cased hole, with an unperforated liner section below the packer or with any known leak point.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 16 – Metal-elastomer Mechanical Annulus Barrier (MAB)

Characteristics	Acceptance Criteria
I. Description	An element formed by one or more metallic sleeves with elastomeric sealing elements that are activated during their installation.
II. Functions	The purpose of the MAB is to provide: a) Sealing the casing annulus or production string/injection line; b) Prevent flow between the inside of the casing or production string/injection line and the annulus.
III. Project/Selection/Construction	1. The MAB must be qualified and tested according to requirements set out in recognized standards (for instance, ISO 14310). 2. The MAB must withstand all anticipated load stresses throughout the life cycle of the well, which are: maximum pressure differential, maximum formation temperature, maximum axial load (tensile and compressive). 3. Other specific conditions such as formation fluids, existing contaminants (H_2S, CO_2 etc.) must be considered when estimating the required MAB lifetime. 4. It must be installed in a section of the well that is compatible with its expansion and with the maximum expected pressure differential for the abandonment period.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the depth at which the seating operation takes place; b) Confirmation by other means: records containing information from the construction stage, informing element depths; c) Confirmation by tagging application, using the work/drill string; d) Confirmation by logging: interpretation of logs that allow presumption of positioning based on typical MAB characteristics: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging enabling presumption of the sealing tightness of the MAB, using methods such as acoustic or flow logs; d) Confirmation by operational parameters: If verification the MAB by applying a pressure differential is impossible, the element can be verified by the operating parameters during its installation. 3. **Remarks:** a) In tightness verifications, by means of confirmation, that require the application of pressure differential, the pressure according to the following assumptions must be defined: i. Must be less than the verification pressure of the previous casing; ii. Must be lower than the buckling pressure of the tubular to which the MAB is connected; iii. Must be greater than the measured or estimated absorption pressure (LOT) of the exposed formation downstream of the pressurized section; iv. Must be lower than the verification pressure of the exposed liners, other exposed equipment or open hole section. b) Pressure Verification of a MAB may be inconclusive and therefore dispensed with, provided the packer meets one of the following conditions: i. Seated in cased hole, above an element (or set of elements) whose tightness was verified, with valid result (see item 6, 1st paragraph); ii. Seated in cased hole, with a section of liner below the MAB that is not perforated or has no known leak point.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 17 – Double Seal Valve (DSV)

Characteristics	Acceptance Criteria
I. Description	The DSV is a seal valve capable to handle two different fluids, seated in the annulus of certain types of production tubing hangers, normally closed, and opened by the stab in the THRT or WCT.
II. Functions	1. Provide hydraulic isolation between the string annulus and production casing and the seabed in the upward direction when in the closed. 2. Allow downwards pressure closure confirmation and hydraulic access when open.
III. Project/Selection/Construction	1. The DSV should be designed for the maximum stresses expected during the abandonment period, seabed temperature and presence of formation contaminants. 2. Should be designed to close and provide isolation of the annulus in the upward direction when a THRT or WCT stab is withdrawn. 3. The element must allow for downwards pressure confirmation to infer that the valve is in the closed position by providing isolation between the casing annulus and production liner and the seabed.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by other means: records containing construction stage information, reporting presence of the element or its visualization; b) Confirmation by operational parameters: at installation, by recording the depth at which the seating operation was carried out. 2. **Tightness:** I. Interventions with direct access to the casing hanger: tightness must be verified by one of the following methods, by using a THRT with retrievable stab, a specific tool or a BOP and subsea kill/choke lines to perform: a) Test (preferable method); b) Confirmation by pressure application. Remaining interventions: in these cases, verification the tightness of the DSV is not feasible before disconnection of the intervention unit, and must be verified by: a) Confirmation by other means: visual inspection of the top of the casing hanger, verifying the closed status of the valve and absence of leakage. 3. **Remarks:** a) If pressure verification is performed using volumetric criteria, the reference pressurizations with the valve still in the open position and after closed must be conducted with careful recording of the returned and pumped volumes.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 18 – Formation isolation valve (FIV)

Characteristics	Acceptance Criteria
I. Description	A tubular element containing a device for isolating the formation and the interior of the production string/injection line. This device is usually of the fail-as-is type and can be actuated mechanically or hydraulically (for instance: FIV, HFIV, slide sleeves).
II. Functions	To prevent fluid flow between the formation and inside the production string/injection line, downwards & upwards (formation vs. surface and vice-versa).
III. Project/Selection/Construction	1. Must be designed to provide sealing to the maximum expected pressure differential during the abandonment period. 2. The metallic materials and elastomers must be compatible with the temperatures and fluids that will be in contact with the valve (for instance, brine, H_2S and CO_2) during the abandonment period..
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by other means: by means of logs containing information from the construction stage, informing element depths or presumption of positioning based on interpretation of acoustic pulses emitted into the well and reflected by the element; b) Confirmation by logging: interpretation of logs that allow presumption of positioning based on typical characteristics of the production string/injection line and formation isolation valve: presence of metallic material, depths of connectors, diameter, etc.; c) Confirmation by tagging: using coiled tubing or wireline/cable; d) Confirmation by operational parameters: analysis of points where nipples were located or where a diameter variation occurred in gauging maneuvers. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging enabling presumption of valve tightness, using methods such as acoustic or flow logs.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 19 – Wellhead annulus access valve

Characteristics	Acceptance Criteria
I. Description	Equipment for access to the well annulus.
II. Functions	Its purpose is to provide opening and closing flow control into/out of the well annulus.
III. Project/Selection/Construction	1. The access point and valve shall be of pressure class equal to or greater than the wellhead/Christmas tree. 2. The valve must: a) Be designed, qualified, tested and manufactured according to recognized industry standards; b) Be able to seal the annulus fluid. 3. When used in combination with annulus injection into the well (e.g. gas lift), the valve must be: a) Surface controlled; b) It is recommended that the effects of low temperature cycles be considered. 4. The valve must be dimensioned according to the type of fluid, temperature and maximum expected well annulus pressure.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by other means: visual inspection of the wellhead. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 20 – Subsea Safety Device (SSSD)

Characteristics	Acceptance Criteria
I. Description	Element that connects to the production string/injection line containing a fail-safe close valve. This valve can be actuated remotely or opened by flow (injection safety valves).
II. Functions	Prevent fluid flow from the formation to the external environment, through the production string/injection line.
III. Project/Selection/Construction	1. Must ensure low pressure sealing (300-500 psi). 2. Must ensure sealing to the maximum expected pressure differential over the abandonment period. 3. The metallic materials and elastomers must be compatible with the temperatures and the fluids that will be in contact with the valve (for instance, brine, H_2S and CO_2) during the abandonment period. 4. Should not be positioned at depth with potential collision risk.
IV. Verification	1. **Positioning: should be verified by one of the following methods:** a) Confirmation by operational parameters: at installation, by recording the elements and the downhole depth; in subsequent interventions, by analyzing the points where location of the seating profiles occurred (nipples) or diameter variation in gauging maneuvers; b) Confirmation by other means: records containing information from the construction stage, informing element depths; c) Confirmation by tagging: using coiled tubing or wireline/cable; d) Confirmation by logging: interpretation of logs that allow presumption of positioning based on typical SSSD characteristics: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging to infer the tightness of the SSSD, using methods such as acoustic or flow logs. 3. **Remarks:** a) After tightness verification it is recommended to carry out pressure trapping below the SSSD that ensures a minimum pressure differential of 500 psi in the flapper during the abandonment period, in order to energize its seals and increase sealing probability.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 21 – Annulus safety valve

Characteristics	Acceptance Criteria
I. Description	Consists of a tubular element with a sealing element that can be activated to isolate the annulus from the well.
II. Functions	The function of the annulus safety valve is to: a) Prevent fluid flow through the annulus between the production string and its tubing; b) Provide an annular seal between the production string and the production tubing.
III. Project/Selection/Construction	1. The sealing element must meet the same requirements as for the production packer. 2. Must be designed to withstand the maximum pressure expected in the abandonment period. 3. Must be installed below the well kick-off point, to allow the possibility of closure below the potential collision point. 4. The valve sealing capacity must be dimensioned according to the highest fluid density in the annulus.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at the installation, by recording the elements and the downhole depth; b) Confirmation by other means: records containing information from the construction stage, informing element depth; c) Confirmation by logging: interpretation of logs that allow presumption of positioning based on typical annulus safety valve characteristics: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging enabling presumption of the tightness of the sealing element, using methods such as acoustic or flow logs. 3. **Remarks:** a) In tightness verifications, by means of confirmation, that require the application of pressure differential, the highest pressure among the values below must be applied, according to the verification direction adopted, with the limit of item v not be exceeded: i. (Downwards) 500 psi above the absorption pressure (LOT) of the weakest formation exposed below the sealing element; ii. (Downwards) 500 psi above the injection pressure at the leak point or completed interval below the sealing element; iii. (Upwards) Upward pressure differential of 300 psi; iv. (Downwards & upwards) The required pressure differential for the test; v (Downwards & upwards) Verification pressure limit of exposed tubulars and remaining exposed equipment/elements. b) Verification by pressure application on the sealing element may be inconclusive and therefore dispensed with, provided the packer meets one of the following conditions: i. Seated in cased hole, above an element (or set of elements) whose tightness was verified, with valid result (see item 6, 1st paragraph); ii. Seated in cased hole, with liner section below the sealing element not torn or with any known leak point.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 22 – Retainer valve (Standing valve)

Characteristics	Acceptance Criteria
I. Description	The element consists of a loss containment device, with a pressure equalization mechanism, metal-to-metal sealing through ball and seat, and elastomeric seals and fishing neck for installation/removal. It can be seated on specific profiles (nipples) or inside a production string (nippleless latch).
II. Functions	Prevent downwards flow in the production string/injection line and, together with the adequate hydrostatics above it, prevent unintentional flow of fluid from the formation to the external environment.
III. Project/Selection/Construction	1. Must be designed to withstand the maximum expected pressure differential for the abandonment period. 2. It must be positioned at a depth such that the hydrostatic pressure above the valve, exerted by the fluid above it, is greater than the maximum potential internal pressure immediately below the valve, during the abandonment period. 3. The metallic materials and elastomers must be compatible with the temperatures and fluids that will be in contact with the check valve (for instance, brine, H_2S and CO_2) during the abandonment period. 4. The riser safety factor should be considered when calculating the weight of fluid to be positioned in the well above the check valve. 5. Must have a mechanism that allows controlled equalization of the upstream and downstream pressures.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by confirming that the depth at which the seating procedure was performed is compatible with the depth of the production string/injection tubing profile; b) Confirmation by other means: by means of logs containing information from the intervention where the element was installed, informing element depths or presumption of positioning based on the interpretation of acoustic pulses emitted into the well and reflected by the element; c) Confirmation by logging: interpretation of logs that allow presumption of positioning of the element installed during a previous intervention, based on typical characteristics of the production string/injection line and the mechanical plug: presence of metallic material, depths of connections, diameter, etc.; d) Confirmation by tagging application: using coiled tubing or wireline/cable to confirm element positioning installed during a previous intervention. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging to infer tightness, using methods such as acoustic or flow logs. 3. **Remarks:** a) Pressure verification of a check valve may be inconclusive and therefore dispensed with, provided that the check valve is positioned above an element (or set of elements) whose tightness has been verified, with valid result (see item 6, 1st paragraph.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 23 – Permanent bridge plug, retrievable bridge plug, cement retainer and abandonment packer

Characteristics	Acceptance Criteria
I. Description	This equipment consists of a plugged tubular body, a device for anchoring it to the casing/liner where it will be seated, and an external body sealing element, which is expanded during installation and ensures sealing between its body and the tubular where it will be seated.
II. Functions	Prevent flow through the interior of the pipe on which it will be seated (liner or production string/injection line) downwards & upwards (formation vs. external environment and vice-versa).
III. Project/Selection/Construction	1. It must ensure sealing tightness to the maximum expected pressure differential over the abandonment period. 2. Must remain anchored to the tubular to be seated at the highest anticipated axial loading condition in the abandonment period. 3. The metallic materials and elastomers must be compatible with the temperatures and fluids that will be in contact with this WB element (for instance, brine, H_2S and CO_2) during the abandonment period.. 4. Must be qualified and tested in accordance with the requirements of ISO 14310 V1 or V0, in case free gas is found at the element's seating depth.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the depth at which the seating operation takes place; b) Confirmation by other means: by means of logs containing information from the intervention where the element was installed, informing depths of the element or presumption of positioning based on interpretation of acoustic pulses emitted into the well and reflected by the element; c) Confirmation by tagging application, using the working/drilling wire to confirm the positioning of the element installed during a previous intervention; d) Confirmation by logging: interpretation of logs that allow presumption of positioning of the element installed during a previous intervention, based on typical characteristics of the element: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging to infer tightness, using methods such as acoustic or flow logs. 3. **Remarks:** a) In tightness verification, with confirmation, demanding pressure differential application, the greater pressure among the values below should be applied, according to the verification direction adopted, with the limit of item v not be exceeded: i. (Downwards) 500 psi above the absorption pressure (LOT) of the weakest formation exposed below the sealing element; ii. (Downwards) 500 psi above the injection pressure at the leak point or completed interval below the sealing element; iii. (Upwards) Upward pressure differential of 300 psi; iv. (Downwards & upwards) The required pressure differential for the test; v. (Downwards & upwards) Verification pressure limit of exposed tubulars and remaining exposed equipment/elements. b) Verification by pressure application on the sealing element may be inconclusive and therefore dispensed with, provided the element meets one of the requirements below: i. Seated in cased hole, above an element (or set of elements) whose tightness was verified, with valid result (see item 6, 1st paragraph); ii. Seated in cased hole, with a section of liner below the non-perforated element or without a known leak point.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 24 – Wellhead

Characteristics	Acceptance Criteria
I. Description	Consists of an element with seals and tubular hangers with sealing assemblies, and may also include annulus access valves.
II. Functions	Its function is to provide mechanical support for the suspended casing and production string and support the riser, BOP and Christmas tree, and prevent flow from the well and annulus to the surface or seabed.
III. Project/Selection/Construction	1. The working pressure of each wellhead stage must be greater than the maximum expected closing pressure for the stage. 2. It must be designed to withstand all anticipated stresses for the abandonment period. 3. For a dry completion wellhead should enable access to all annuli to facilitate observation of annular pressures and fluid injection/drainage. 4. The hanger of the tubulars must be locked, either by packoff or additional locking mechanism, to ensure integrity of the sealing element during the abandonment period.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the elements and the downhole depth; b) Confirmation by other means: records containing information from the construction stage, informing element depths; c) Confirmation by logging: interpretation of logs that allow presumption of its position, based on typical characteristics of the elements: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging that allows presumption of the tightness of the sealing element, using methods such as acoustic or flow logs.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 25 – Production Adapter Base (PAB)

Characteristics	Acceptance Criteria
I. Description	The element consists of an adapter between the wellhead and the WCT, hydraulic connector, sealing ring and, depending on the model, annular access valves.
II. Functions	The element consists of an adapter between the wellhead and the WCT, hydraulic connector, seal ring and, depending on the model, annular access valves. Its function is to provide mechanical support for the hanger and the production string, connection for seating the BOP and WCT, to allow access to the annulus between the production string and its casing (depending on the type), and prevent the flow of hydrocarbons to the environment.
III. Project/Selection/Construction	1. The working pressure of the BAP must be greater than the maximum anticipated pressure at well closure. It must be designed to withstand all anticipated stresses for the abandonment period. 2. There should be annulus access between the production string and its casing to facilitate observation of annular pressure and fluid injection/depressurization, except in cases where this access is accomplished directly through the production string hanger.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the elements and the downhole depth and tension application to confirm its effective locking; b) Confirmation by other means: records containing information from the construction stage, informing element depths or visual inspection of the equipment; c) Confirmation by logging: interpretation of logs that allow presumption of the element position, based on typical characteristics: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging enabling presumption of the tightness of the sealing element, using methods such as acoustic or flow logs.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 26 – Completion Adapter Base (CAB)

Characteristics	Acceptance Criteria
I. Description	This element consists of an adapter between the mudline wellhead type and the WCT, with a high-pressure housing or connector for a Self-Elevating Platform (SEP) in its upper profile with an access valve to the production casing and its annulus, including the seal between the CAB and wellhead and seal between the CAB and the production riser or WCT.
II. Functions	Its function is to provide mechanical support for the hanger and the production riser, a connection for seating the BOP or WCT, or connection of the production riser and landing sub in case of a PAB, to enable access to the annular riser and production riser and prevent flow of hydrocarbons to the environment.
III. Project/Selection/Construction	1. The CAB must be seated and locked over the mudline type subsea wellhead, provide sealing between the tubulars and allow installation of the WCT and TH. 2. Must allow probe access by one of the following methods: a) In the case of well access with floating rig, it should allow the seating of the subsea BOP on the top profile for installation and removal of the TH and operations inside the production casing; b) In the case of access to the well with jackup rig, it should allow the connection with the conductor on the top profile and landing sub on the inner profile for installation and removal of the TH and operations inside the production casing. The conductor casing together with the drilling head will allow interconnection of the surface BOP. 3. The CAB working pressure must be higher than the maximum anticipated pressure for the entire abandonment period. The CAB should be designed to withstand all stresses anticipated during the abandonment period. 4. Must have access to tubing annulus and production casing to facilitate observation of well pressure and fluid injection/depressurization.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the elements and the downhole depth and applying tension to confirm locking; b) Confirmation by other means: records containing information from the construction stage, informing element depths or visual observation of the equipment; d) Confirmation by logging: interpretation of logs that allow presumption of positioning, based on typical characteristics of the elements: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging enabling presumption of the tightness of the sealing element, using methods such as acoustic or flow logs.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 27 – Wet Christmas tree (WCT)

Characteristics	Acceptance Criteria
I. Description	Equipment consisting of valves, a control system and flow lines with the purpose of controlling the production and/or injection of fluids into the well. The WCT can be classified into: Horizontal WCT and Vertical WCT.
II. Functions	1. Provide connection to the subsea wellhead, production adapter base or completion adapter base. 2. Allow intervention from the coupling of the BOP to the Horizontal WCT and the Tree Running Tool (TRT) or to the Vertical WCT through its upper profile. 3. Allow mechanical and hydraulic access to the production string and hydraulic access to the annulus. 4. Provide, depending on its constructive characteristics, sensors for observation of pressures and temperatures. 5. Provide interfaces with the subsea production/injection lines and access to the annulus and the control and injection umbilicals. 6. Provide flow interruption in the production string/injection line and annulus between tubulars and their casings by closing valves.
III. Project/Selection/Construction	1. The WCT hydraulic connectors must have a positive locking system (keeping the equipment connected without need for assisted pressure), control line for testing the sealing ring and an unlocking system. 2. Must have the capacity to withstand internal and external pressures, tension stresses, bending moments and other stresses generated during an intervention operation and during the abandonment period. 3. The WCT for producing wells shall be equipped with at least: a) Master-type valves at the production and annular bores; b) Wing type valves on the production and annular bores; c) Swab-type valves in vertical WCTs and profiles for production plugs in horizontal WCTs; d) Isolation valves for block and well access control lines. 4. Must have an operation panel to actuate valves with use of a ROV or interface for actuating with diver operated or diver assisted valves.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the elements and the downhole depth and tension application to confirm effective locking; b) Confirmation by other means: records containing information from the construction stage, informing element depths or visual inspection of the equipment; c) Confirmation by logging: interpretation of logs that allow presumption of the element position, based on typical characteristics: presence of metallic material, depths of connections, diameter, etc. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging enabling presumption of the tightness of the sealing element, using methods such as acoustic or flow logs.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 28 – Dry Christmas tree (DXT)

Characteristics	Acceptance Criteria
I. Description	Equipment consisting of valves, control system, flow lines and interface seals for the purpose of controlling the production and/or injection of fluids into the well.
II. Functions	1. Provide a path for fluids coming from the production string to the surface lines with the capacity to stop or control the flow downwards & upwards. 2. Provide an access point through which a kill fluid can be pumped into the production string. 3. Provide an access point to the well.
III. Project/Selection/Construction	The VCT must be designed according to the type of fluids, temperatures, and the maximum anticipated wellhead pressure. 1. For flowing wells, the VCT must be equipped, at least, with a production valve in the well's main flow path, a swab valve (not applicable to Horizontal Christmas trees), and a master valve. 2. For non-flowing wells, the VCT must be equipped at least with one production valve.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by registering the element and applying tension to confirm effective locking; b) Confirmation by other means: records containing information from the construction stage, informing element presence or visual inspection of the equipment. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging that allows presumption of the tightness of the sealing element, using methods such as acoustic or flow logs.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 29 – Surface isolation valve

Characteristics	Acceptance Criteria
I. Description	A shut-off valve installed in an onshore well, pending its completion, positioned on the last downhole spool (cased hole), on the production head (production casing to the surface) or on the end of the casing. In the latter case, the well remains without the production head and the valve is directly threaded onto the casing.
II. Functions	1. Act as an WB element capable of keeping the well closed by preventing the unintentional flow of fluids from the formation to the external environment. 2. Allow depressurization or injection into the well and the installation of pressure gauging devices.
III. Project/Selection/Construction	1. Must have the same or higher pressure class as the remaining well surface equipment and can be opened at any time. 2. Must be compatible with the fluid type, temperatures, and the maximum expected well pressure.
IV. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the element; b) Confirmation by other means: records containing information from the construction stage, informing element presence or visual inspection of the equipment. 2. **Tightness:** must be verified by one of the following methods: a) Test (preferable method); b) Confirmation by pressure application; c) Confirmation by logging that allows presumption of the tightness of the sealing element, using methods such as acoustic or flow logs.
V. Applicable Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 30 – Fluid

Characteristics	Acceptance Criteria
I. Description	Fluid column inside the well not linked to mechanical containment/retention element(s) installed inside the well.
II. Functions	The function of the fluid as an WB element is to exert sufficient hydrostatic pressure in the well to prevent unwanted fluid inflow from the formation into the well.
III. Project/Construction/Selection	1. The resulting minimum hydrostatic pressure regarding the permo-porous interval must be equal to the estimated or measured pore pressure of the reservoir added by a safety factor. 2. The maximum resultant hydrostatic pressure regarding the permo-porous interval must not exceed the formation fracture in open hole, including a safety factor. 3. For application in subsea wells where the well is in contact with the seabed, it should be considered that the pressure acting at the depth is the hydrostatic pressure of the water sheet. 4. When in contact with the seabed, the fluid formulation should be appropriate for contact with the external environment. 5. The specifications and critical properties of the fluid should be described prior to its use as an WB element. 6. The specific mass should be stable considering the specified tolerances under well condition for the duration of the designed temporary abandonment. 7. The composition of the fluid should be stable during the abandonment period. To this end, its formulation should be designed to maintain integrity of the critical fluid properties, considering aspects such as decantation, thermal and microbiological degrading, as well as tolerances specified under well condition. 8. When in contact with the seabed, the influence of diffusion and convection effects on the reduction of the equivalent pressure of the hydrostatic column must be considered in its design. 9. When the element is positioned over a primary WB composed of mechanical elements, the fluid specific mass dimensioning should consider the extrapolated pressure of the permo-porous formation by the fluid gradient predicted from the formation to the depth of the mechanical WB base. 10. The acceptable loss level should be defined in the design. When necessary, a stop loss operation should be scheduled until the acceptable level is reached. 11. The element should be sized so that in the event of failure of the mechanical WB element below, no inflow to the external medium/surface occurs. 12. The element shall have the ability to plug the permo-porous formation through particulate materials suitable to the formation characteristics. 13. When in contact with the seabed and if the specific mass required for the fluid is less than or equal to the specific mass of seawater, non-plugging of the formation is allowed, provided that the possible impact of seawater injection on the permo-porous formation is analyzed and considered acceptable from the point of view of preservation of the oil deposit and well safety. 14. A record should be kept regarding the definition of the maximum usage time of the fluid as an WB element. 15. During its use as WB element, continuous monitoring of both the level and properties of the fluid is dispensed with.
V. Verification	1. **Positioning:** should be verified by one of the following methods: a) Confirmation by operational parameters: at installation, by recording the pumped and displaced volume of the element and its measured specific mass, along with the hydraulic circuit used, confirming that the well is filled according to the anticipated volume; b) Confirmation by other means: records that contain information from the construction stage, informing element; c) Confirmation by logging: interpretation of logs that allow presumption of the element position based on typical characteristics: specific mass, hydrostatic pressure, etc. 2. **Tightness:** must be verified by one of the following methods: a) Testing, through direct exposure of the fluid to the pertinent interval; b) Confirmation by pressure application, by simulating overpressure regarding the pertinent interval with a fluid different from the one to be used for the abandonment period; c) Confirmation by logging enabling presumption of the effectiveness of the fluid as WB element, such as pressure or fluid gradient profiles; d) Confirmation by other means: based on the variation of the fluid level interpreted from acoustic pulses emitted to the well and reflected by the element. 2. **Remarks:** a) Verification the WB effectiveness shall evaluate the achievement of the acceptable loss level established by design (item III.10 of this Table); b) If the element is positioned on a primary WB composed of mechanical elements, these elements shall be verified in compliance with the respective EAC Table, and in this condition the cessation of eventual fluid loss to the formation is expected.
V. Abandonment Type	Permanent – N/A Temporary - Yes

Source: Prepared by the Authors.

Table 31 – Perforate, Wash and Cement (PWC)

Characteristics	Acceptance Criteria
I. Description	This WB element consists of the cement barrier positioned, with the Perforate, Wash and Cement method, in the annulus(i) between the casing(s)/liner(s) and/or the wall of the open hole, as well as the cement plug positioned inside the tubular.
II. Functions	Provide continuous, permanent sealing along a perforated tubular interval, both at the annulus and inside, to prevent flow between formation intervals or to the external environment.
III. Project/ Construction/Selection	1. A program must be issued for each PWC operation covering at least the following contents: a) Base requirements of the element, both inside and in the annulus(i) of the tubular(s); b) Dimension and density of the perforations to be made in the tubular; c) Parameters for the wash and pumping/displacement of fluids and slurries of the cementation operation; d) Properties of the fluids and slurries to be used in the operation. 2. The resulting cement plug inside the tubular must be designed according to the EAC Table 3. 3. The minimum length of the drilled interval where the PWC operation will be performed shall be 30 m for 1 (one) WB element and the provisions of items 4.3.2 and 4.3.2.1 shall be observed. 4. The minimum length of the drilled interval where PWC operation will take place, in order to be a combined WB element, is twice the respective length mentioned in item 3.
IV. Verification	1. **Positioning:** the length and positioning of the cement in annulus should be verified by one of the following methods: a) Confirmation by logging: profiling tools/methods should be chosen based on the capacity to provide data for inference of cement positioning. Profiles should be analyzed and the analysis documented; b) Confirmation by operational parameters: records of the cementing operation that allow to infer the position of the cement in the annulus(i), such as, for instance, agreement with the operating parameters (flow rate, pressure, speed of movement of the working string or coiled tubing, pumped and returned volumes without indicating loss of circulation or inflow etc.); c) Confirmation by other means: records containing information from the construction stage, informing element depths. 2. **Tightness:** must be verified by one of the following methods: a) Confirmation by logging: profiling tools/methods should be chosen based on their capacity to provide data for verification of the cementing quality (hydraulic isolation inference), such as acoustic (sonic or ultrasonic), flow or saturation logs. The logs should be analyzed and the analysis documented; b) Confirmation by operational parameters: records of the cementing operation attesting the normality of the operation (flow, pressure, speed of movement of the working string or coiled tubing, pumped and returned volumes not indicating loss of circulation or inflow, etc.; c) Test: by establishing a pressure differential over the cement sheath; d) Confirmation by pressure application: by establishing a pressure differential on the cement sheath. 3. **Remarks:** a) No pressurization on the cement should not be carried out during the gelling process of the cement slurry, but may be applied while the slurry is still fluid or after having acquired sufficient compressive strength; b) In cases of circulation loss, it must be documented that the interval with loss is above the planned top of the cement slurry. An example of acceptable documentation is the operational comparison of a correlation well in which a similar loss occurred and which had sufficient length verified by profiling; c) Methodologies to compensate for the absence of operational parameter records should be employed as a complement to the information to be analyzed and interpreted for the verification of cement in annulus. In this sense, retrograde analysis and computer simulations can be employed; d) To make the confirmation by operational parameters viable, the qualification of the PWC operation must be carried out by obtaining a track record of success in a correlation scenario (similarity of geometries, lithology and fluid systems) where the operating parameters are recorded. e) The resulting Cement plug inside the tubular shall be verified according to the EAC 3 table; f) For permanent abandonment: after the PWC operation, the casing section used to make up the WB(s) will be perforated and cemented along its length, and is considered as not having an objective verification criteria, for being the cemented intervals (inner well and annulus) that should provide the seal and integrity of the WB; g) For temporary abandonment: the casing section used to make up the temporary WB has no objective verification criteria, for being the cemented intervals (annulus and, where appropriate, well interior) that should provide the sealing and integrity of the WB.
V. Abandonment Type	Permanent - Yes Temporary - Yes

Source: Prepared by the Authors.

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OPERATIONS COMMITTEE

On June 24, 2024, an email was received from 3R Petroleum requesting clarification regarding the understanding/interpretation that shall be given to the term "length" used in the E&P Best Practices Booklet – Well Abandonment Guidelines (IBP, 2022), as the ANP would be adopting a different interpretation from that practiced by the company's technical team in the use of the handbook published by IBP.

On June 28, 2024, a request of the same nature was received in the email mailto:CBPabandono@ibp.org.br from Petrobras.

To answer the request, the following analysis was carried out:

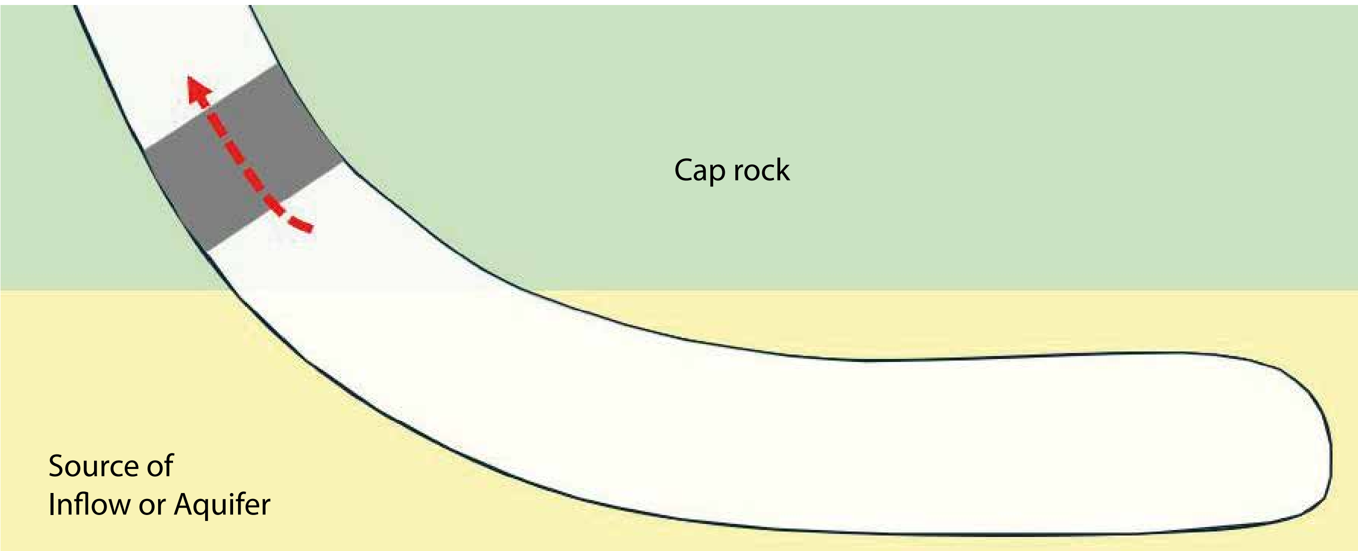
From the technical analysis

The IBP's Best Practices Booklet – Well Abandonment Guidelines (2022) repeatedly uses the term **"length"** to define the extension of the barrier (WB elements) to be installed, and, in the understanding of the Operations Committee Technical Group, when this term was adopted, since the first version of the Booklet published in 2017, there was no doubt about its interpretation: **this term denotes the difference between the measured depth from base to top of the WBE under evaluation**.

This understanding is based on the technical analysis that, for the leakage risk introduced by well construction – which is what is intended to be avoided with the barrier – to occur, the path to be overcome by the formation fluid is the route along the element.

The figure below illustrates the issue, where it can be seen that, to mitigate the leakage risk introduced by well construction, a barrier with sufficient length must be installed to prevent flow along the barrier.

Figure 1 – Schematic illustration (not to scale) of a barrier installed in a well



Source: Prepared by the Authors.

In this sense, in a scenario where the WBE is installed in a deviated section (as illustrated in the figure), it is absolutely normal and expected that the vertical height (difference between vertical depth from base to top) will be lower than the length (difference between measured depth from base to top), as it is a mere trigonometric observation. However, this does **not** imply any difference in terms of risk level when compared to the vertical well scenario, since in both cases, the barrier extension that the formation fluid would have to overcome to bypass the barrier along the well is exactly the same.

It is also worth noting that both the Brazilian and UK handbooks explicitly mention the case in which a barrier is installed at high inclination, respectively in their items *"5.2 Horizontal or High Angle Wells (wells > 70°)"* and *"3.6.6 Additional Considerations for High Angle and Horizontal Wells (wells > 70°)"*, and both adopt the same approach, indicating that, in principle, the abandonment requirements for a horizontal or directional well with high inclination do not differ from those for a conventional (low inclination) well, but highlighting the necessary care for successful cementing in high inclination.

Despite the above, there could be concern regarding the "restoration of the cap rock", a principle that guides the philosophy of permanent WB currently adopted not only in Brazil but also in recognized jurisdictions abroad. In this sense, it is worth noting that the current requirement to be observed, according to the Brazilian best practices booklet, is that, at the base of the WB, there must be a sealing formation with adequate competence to withstand the loads of the formation to be isolated, as can be inferred from the reading of item *"4.3.1 Positioning Requirements"*, which states:

> *The permanent WB elements must:*
>
> *» Have geometrically coincident bases seated at the planned depth to constitute an WB;*
>
> *» Exist in the inside and in the annuli of the tubulars along the cross section;*
>
> *» Have their bases placed across a sealing formation (caprock) according to the EAC 8 table."*

Thus, it can be seen that there is no objective guidance regarding the vertical height of the barrier that should be established in order to "restore the cap rock", which is not a particularity of the Brazilian booklet, as the same can be observed in other recognized handbooks such as Norsok D-010 - Well integrity in drilling and well operations (Rev. 5, 2021) and OEUK Well Decommissioning Guidelines (Rev. 6, 2022).

The reason for this apparent omission is due to the little influence of this parameter, since geomechanical studies conducted by operators demonstrate comprehensively that minimum lengths of sealing rock are capable of acting adequately as a barrier.

In this sense, it is worth noting that impermeability is a characteristic of the rock, and this property is not related to the length of the rock. Regarding the stress regime of the rock, it is observed that although it is altered by well drilling, it returns to its original (in situ) values at a distance of the typical order of 3 well radii from the well[1]. That is, in the case of a 12 ¼" (diameter) drilled section, the sealing formation would already have its original properties (in situ) at a distance of 18.4" (0.47 m). As an illustration, considering the classic length indicated for the "cement plug" element (30 meters), it can be observed that the vertical height of the element would be less than 0.47 meter only in a scenario where the well inclination is greater than 89.1°.

[1] It should be noted that this is a conservative analysis that considers the interaction between rock and fluid, as after the casing is run and cemented, there is likely a relief in these stresses until equilibrium is reached again.

Regarding the definition of the shallowest depth for positioning the base of the WB, the evaluation of the competence at the base of the sealing formation, according to the method provided in item *"4.3.1 Positioning Requirements"*, where the crossing point between the potential internal pressure of the interval with potential flow and the strength of the sealing formation is identified, is sufficient to ensure that the barrier is within a competent range.

Therefore, in order to avoid any doubt regarding the adequacy of the barrier, it is clear that there is room for improvement in best practices by explicitly stating a conservative recommendation so that, in the absence of a specific study for the well/barrier[2]:

i. The vertical height of the "restored cap rock" section by the PWB should not be less than 5 well radii;

ii. The minimum vertical distance between the base of the PWB and the top of the formation to be isolated (interval with potential flow or aquifer) should not be less than 5 well radii.

Additionally, it is important to note that defining a minimum length for the WBE should not be understood as the *volume of cementing material to be pumped by the operator*, and the Booklet is absolutely clear about this, as can be seen in item *"4.3.2 Length Requirements"* which states:

> *For elements based on the application of cement or alternative material subject to contamination, to achieve higher reliability of the WB element, the planned length for placement operations of cement or alternative material should be greater than the minimum length required for an WB element.*

A similar observation can also be found in the UK best practices document, which, for example, in its item *"3.6.1 Cement Plug Placement Using a Stinger"* indicates that *"to achieve the required barrier length, allowances will have to be made on volumes to cater for uncertainties during placement. It may be necessary to place up to 500 ft MD of cement to achieve 100 ft of good cement. Similarly, it may be necessary to place up to 800 ft MD of cement to achieve 200 ft"*.

It is important to highlight that, in some cases, depending on the scope to be executed and the mechanical configuration of the well, the excess cementing material pumped may be washed/drilled after the positioning operation of the permanent barrier, which does not cause any harm to the remaining length in the well, since the main objective of the excess pumped material is to prevent the contamination of the cement slurry by the well fluids during displacement to the final depth. In other words, removing the excess after having the WBE positioned at its final depth will not result in any harm to the quality of WBE.

Finally, considering the jurisdictions that inspired much of the content of the IBP Best Practices Booklet, it is known that the philosophy of Element Acceptance Criteria Tables ("EAC Table") was incorporated from Norway, while the definitions of length, positioning, and verification were more aligned with the United Kingdom.

Regarding the "sealing formation" element, it should be noted that the approach currently adopted in the IBP Booklet is the same as that practiced in the North Sea countries, that is, without a minimum vertical height.

[2] Study supporting the adoption of vertical height and/or vertical distance lower than recommended in this document.

Conclusion

It is clarified that **the term "length," used in the references to the extension of the WBE, denotes the difference between the measured depth from the base to the top of the evaluated WBE**, since technically it is the path along the barrier that would need to be overcome for the well-related leakage to occur.

Additionally, it is observed that the technical understanding is aligned with that practiced in jurisdictions recognized for their technical framework for well abandonment.

Conservatively (and as a pioneer for the global industry), to dispel any doubts regarding the adequacy of the positioning and length of the permanent WB, it is recommended to explicitly state and adopt the following practices[3]:

i. **The vertical height of the "restored cap rock" section by the PWB should not be less than 5 well radii[4];**

ii. **The minimum vertical distance between the base of the PWB and the top of the formation to be isolated (interval with potential flow or aquifer) should not be less than 5 well radii.**

Finally, it is emphasized that the channel indicated in the Introduction of the Booklet is available for consultation ("The E&P Good Practices Booklet – Well Abandonment Guidelines is subject to periodic reviews. Feedbacks, comments and consultations for clarifications can be forwarded by e-mail to: mailto:CBPabandono@ibp.org.br"), making it clear that this channel is available not only for operators/members of the IBP but for the entire industry that uses and is or may be affected by the content of the document. It is beneficial that changes in understanding/interpretation be preceded by a request for clarification through the mentioned channel to avoid unnecessary disruptions in industry activities.

Flavio Torres
Executive Manager of HSE and Operations

[3] For values lower than those indicated, the operator must produce a technical study supporting the case.
[4] Well radius = half the diameter of the drill/bit/reamer that drilled/reamed the depth at which the WB will be installed.

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