Annular Barrier as an Alternative to Squeezes in Challenging Wells: Technology Review and Case Histories*

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Search and Discovery Article #70249 (2017)**
Posted April 3, 2017

*Adapted from oral presentation given at AAPG/SPE 2016 Africa Energy and Technology Conference, Nairobi City, Kenya, December 5-7, 2016

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Abstract

The drilling industry has always relied on cement as a primary barrier. Although the cement represents about 5% of the well cost, when squeezes are required, cementing averages 17% of the well cost. Only 50% of the squeezes achieve the objective of establishing a barrier for well integrity. A little bit more than half of the failures can be attributed to operational challenges (pump failure, cement contamination), or design oversights (cement recipe, centralizers). However there are still cement failures with perfect design and field execution. These failures typically exhibit some of the following characteristics: high deviation, high pressure, washouts, natural fractures, long casing section, heterogeneous sands. For these specific conditions, it is beneficial to add an assurance that would maintain the integrity of the well even in case of bad cement. Some of the assurances used include port collars, external casing packers (ECP), and swell packers. Port collars allow a squeeze above the first stage cement, while ECP serves as a base for a second stage cement, and swell packers provides a baffle for sustained casing pressure. A more recent technology is the well annular barrier that can form a combined barrier with cement, and can also be used as a stand-alone primary barrier. The well annular barrier is a metal-expandable barrier that is expanded with hydraulic pressure. It is full bore, highly customizable, and qualified to ISO 14310. The metallurgy allows the packer to shape fit into either an open hole with irregular geometry or inside a casing to preclude annular pressure build up by giving a life-of-well reliable seal. The well annular barrier has been deployed in a variety of wells to achieve well integrity with and without cement, protect the B-annulus from sustained casing pressure, or serve as a barrier between reservoirs that cannot be commingled. This paper performs a review of the technologies used for cement assurance, their advantages and disadvantages. Case histories of well annular barrier deployments are presented, including a case where the well annular barrier was used as a stand-alone well barrier element without the need for dispensation. This paper also discusses how the well annular barrier fits into the regulatory requirements for well construction providing to the drilling industry an alternative to cement for the purpose of well integrity.

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Statistics on Cement

- Primary cementing cost = 5% of well cost
- Primary cement jobs that require squeezing = 15%
- Total cost of cementing with squeeze = 17% of well cost
- Typical number of squeezes to fix a primary cement job = 3
- Success rate of squeezes = 50%

Source: *George E. King Consulting*

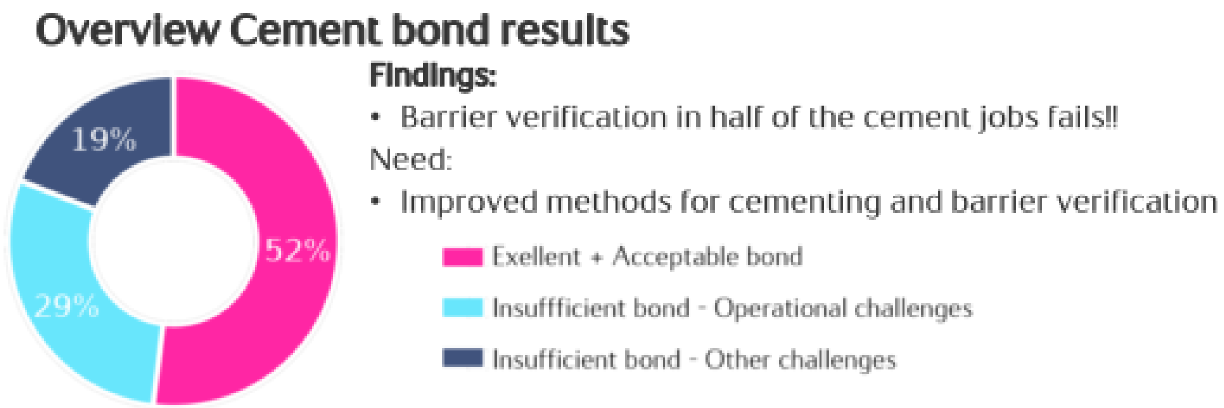


Figure 1: Major IOC Review of 96 Cement Operations

When Shall Cement Assurance be Considered?

- Deviation > 45^o
- Thin shale separation < 50 ft
- Pressure difference between zones in the same section
- Presence of gas
- Natural fractures
- Washouts
- Long sections

Port Collar for Cement Assurance

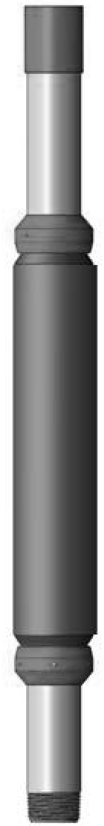
- Category: sliding sleeve
- Advantage:
  - Improved casing integrity compared to casing punch
- Disadvantages:
  - Communication path
  - Position selection
  - Second stage cement success

External Casing Packer for Cement Assurance

- Category: inflatable packer
- Advantage:
  - Second stage cement enabler
- Disadvantages:
  - Short term seal
  - Fragile
  - Differential pressure rating

Swell Packer for Cement Assurance

- Category: swelling rubbers
- Advantage:
  - No moving parts and inflation not required
- Disadvantages:
  - Fluid for swelling
  - Swelling time
  - Differential pressure rating

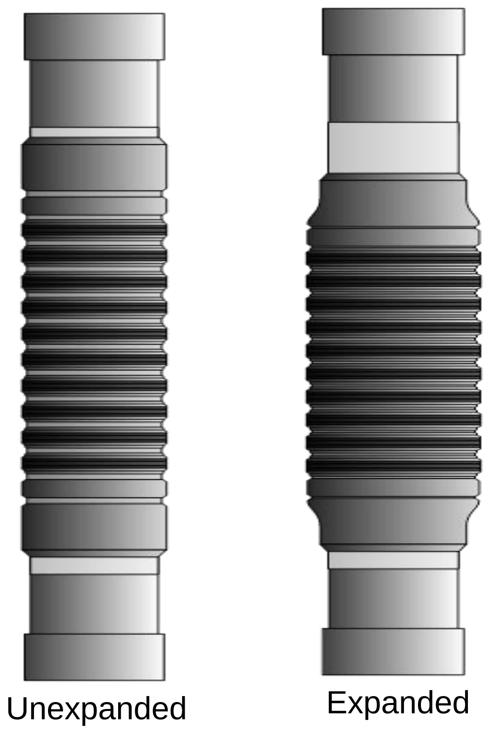


Well Annular Barrier for Cement Assurance

- Category: metal-expandable barrier

- Advantages:
  - Annular seal independent from cement success
  - Life-of-well seal
  - Ruggedized
  - Differential pressure rating
  - Fluids compatibility
  - Expansion time

- Disadvantage:
  - Pressure tight system required for expansion



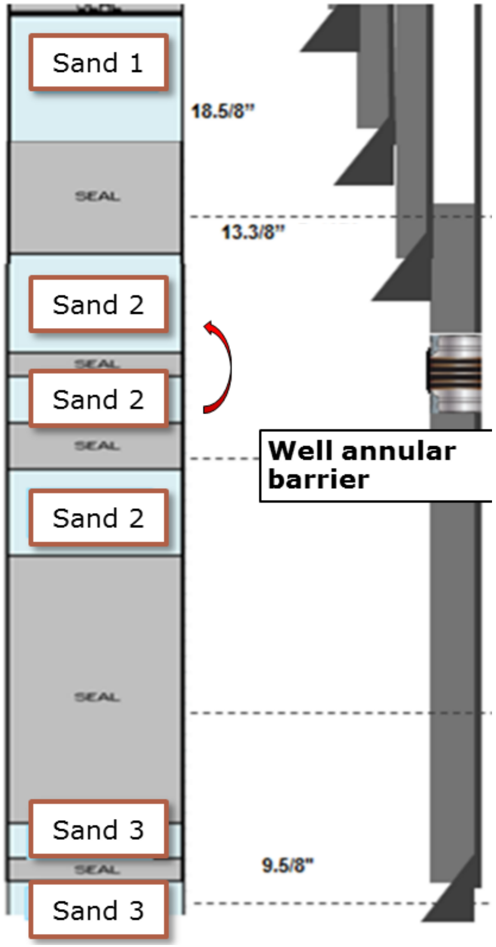
Case History 1 – Prevention of Crossflow while Cement is Curing

Challenge
- Poor well integrity due to crossflow between adjacent zones while cement is curing

Solution
- 1 x well annular barrier mounted on the 9 5/8" casing
- Sealing against 12 ¼" open hole
- Qualifications to ISO14310
  - Sleeve ΔP: 6,000 psi V3 & 1,500 psi V0
  - Expansion port ΔP: 11,000 psi V3 & 7,500 psi V0

Operation
- Obstruction met while RIH
- Partial losses during primary cement
- Well annular barrier expanded in green cement

Achievement
- Combined well barrier established successfully



Case History 2 – Prevention of Severe Scaling Issues

Challenge

- Thin shale separation (3-4m) between water zone and reservoir at 79º deviation
- Well shut-in within 24 hrs due to scale

Solution

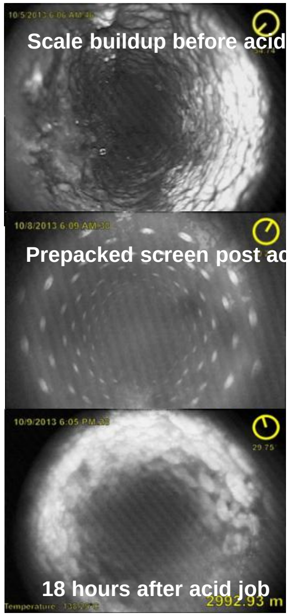
- 2 x well annular barrier mounted on 9 5/8" casing
- Sealing against 12 ¼" open hole

Operation

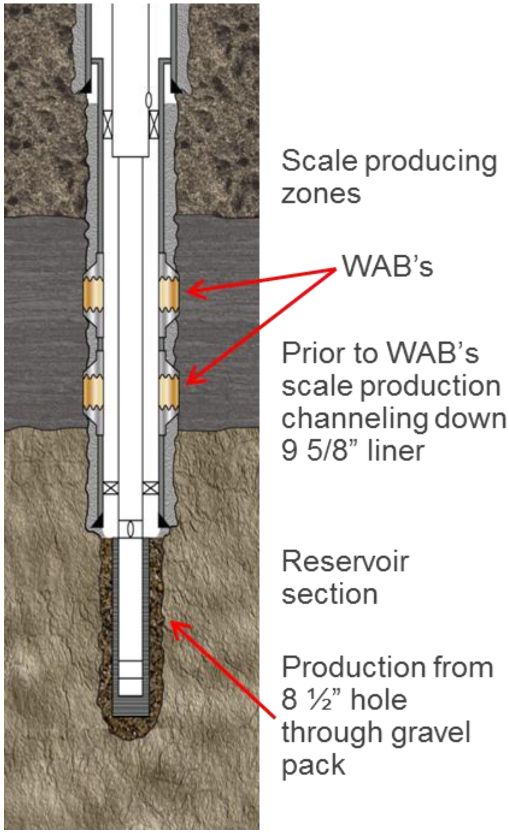
- Deployment through a milled window
- Plug bumped later than planned
- Well annular barrier expanded in green cement

Achievement

- Combined well barrier established successfully
- Scale free production



Main Bore



Side Track

Case History 3 – Standalone Primary Barrier without Cement

Challenge

- Field with history of annular pressure buildup due to gas charged sand below the 13 3/8” casing shoe

Solution

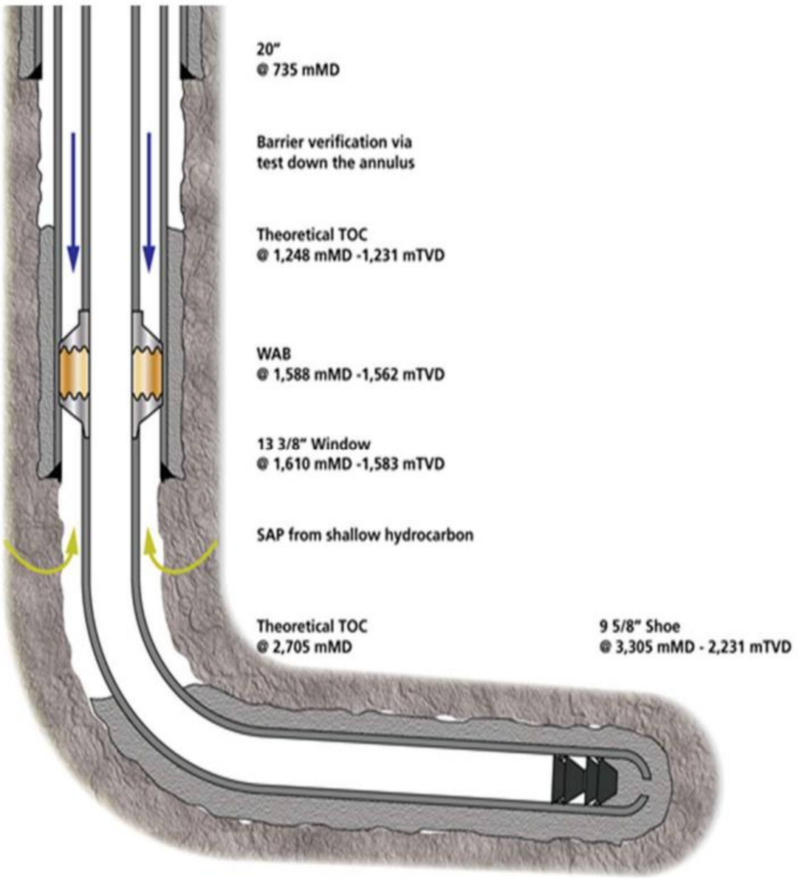
- 1 x well annular barrier mounted on the 9 5/8” casing
- Sealing against 13 3/8” casing
- Qualifications ISO14310:
  - Sleeve ΔP: 5,000 psi V3 & 1,500 psi V0
  - Expansion port ΔP: 10,000 psi V3 & 5,000 psi V0

Operation

- Cement focused around 9 5/8” casing shoe
- Well annular barrier expanded after bumping the plug
- Barrier verification via surface pressure in the annulus

Achievement

- First primary barrier without cement
- No dispensation required from the regulator



Regulatory Requirements based on NORSOK-D010

Table 4 – EAC table description

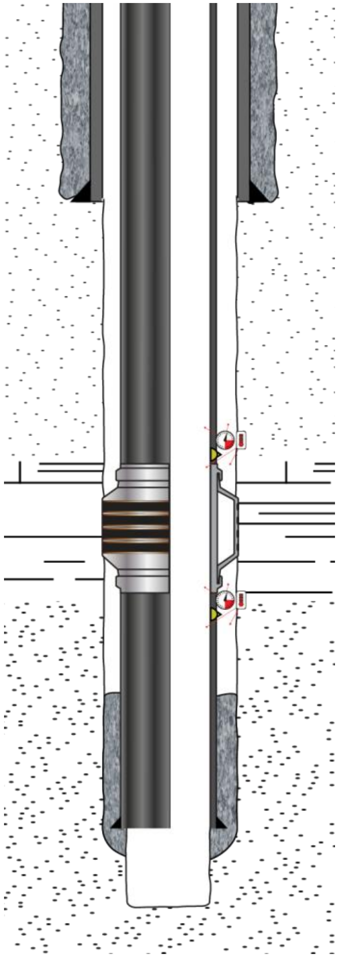
Features	Acceptance criteria	See
A. Description	This is a description of the WBE	
B. Function	This describes the main function of the WBE	
C. Design (capacity, rating, and function), construction and selection	For WBEs that are constructed in the field (e.g. drilling fluid, cement), this should describe a) design criteria, such as maximal load conditions that the WBE shall withstand and other functional requirements for the period that the WBE will be used, b) construction requirements for the WBE or its sub-components, and will in most cases consist of references to normative standards.	Name of specific references
	For WBEs that are pre-manufactured (production packer, DHSV), the focus should be on selection parameters for choosing the right equipment and proper field installation	
D. Initial test and verification	This describes the methodology for verifying the WBE being ready for use and being accepted as part of a well barrier	
E. Use	This describes proper use of the WBE in order for it to maintain its function during execution of activities and operations	
F. Monitoring (regular surveillance, testing and verification)	This describes the methods for verifying that the WBE continues to be intact and fulfils the design criteria	
G. Common WBE	This describes additional criteria to the above when this element is a common WBE	

Guidelines for a Compliant Pre-Manufactured WBE

WBE design
- Qualifications to ISO14310
- Accelerated aging test for life-of-well

Barrier verification in cased hole
- Annular pressure from surface
- Pressure above WBE > frac gradient

Barrier verification in open hole
- Set WBE in a compliant formation
- Install annular gauges above and below the WBE
- Read pressure differential across WBE



Conclusion

Well annular barrier

- Achieves successful cement assurance
- Achieves a more robust well integrity
- Achieves a primary stand-alone barrier
- Paves the way for simplified well construction
- Overall reduces time, improves safety, reduces cost