Annular barriers verification and acceptance criteria

HAVTIL’s Fagdag: Plugging og forlating

Laurent Delabroy – Discipline Lead, Cement & Zonal Isolation

07 May 2024

NORSOK D-010:2021

Table C.22 — EAC Table 22 – Annulus cement

Features	Acceptance criteria
A. Description	This element consists of cement in solid state located in the annulus between concentric casing strings, or the casing/liner and the formation.

2) The cement length shall be verified by one c

a) Bonding logs: Logging methods/tools s
on ability to provide data for verificati
measurements shall provide azimuthal
logs shall be verified by qualified perso

b) Displacement calculations: Actual para
displacement rate, pressure profile, vo
should be compared with simulations u
recognized software to take into accou
properties and friction contribution. Th
parameters deviating from plan should
losses, it shall be documented that the
planned top of cement. Acceptable documentation is job record
comparison with similar loss case(s) on a reference well that
has achieved sufficient length verified by logging.

Bond logging mandatory for ***dual*** annular cement barrier verification as well as for creeping shale barrier verification

Note that there are different methods to verify the integrity of annular barriers, besides a [redacted] logging; passive noise logging, temperature logging, and [redacted] are among the most commonly used verification methods. New tools using multi-physics or nuclear measurements, and new techniques using tracer gas are also being developed.

20th April 2016

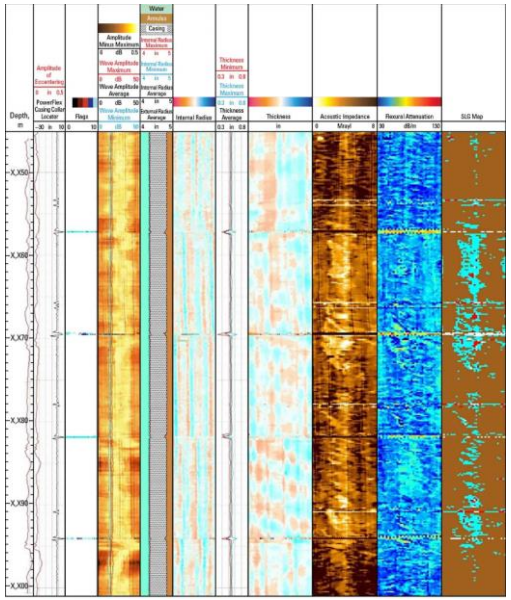
Can we trust acoustic cement bond logging?

Wouldn't it be nice if we could:

- Visually inspect cement that has been in an oil well for decades and assess its quality in a direct, measurable way?

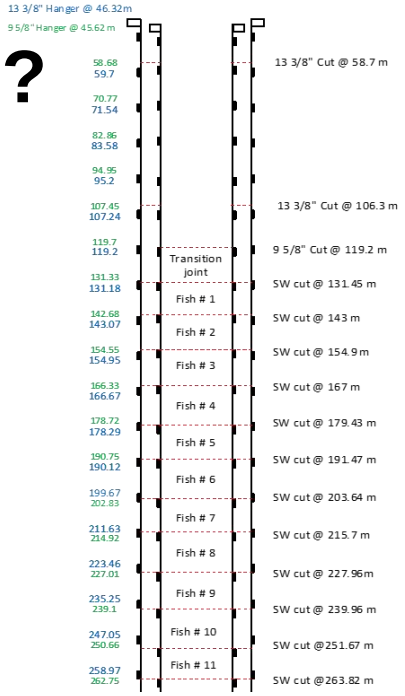
AND

- Determine how good a correlation there is, between the quality of a cement bond (determined via cement bond logs) and physical leakage?



Can we trust acoustic cement bond logging?

SPE 199609
An Evaluation of the Cement Sheath Quality of Casing Sections Recovered During a Well Abandonment Operation

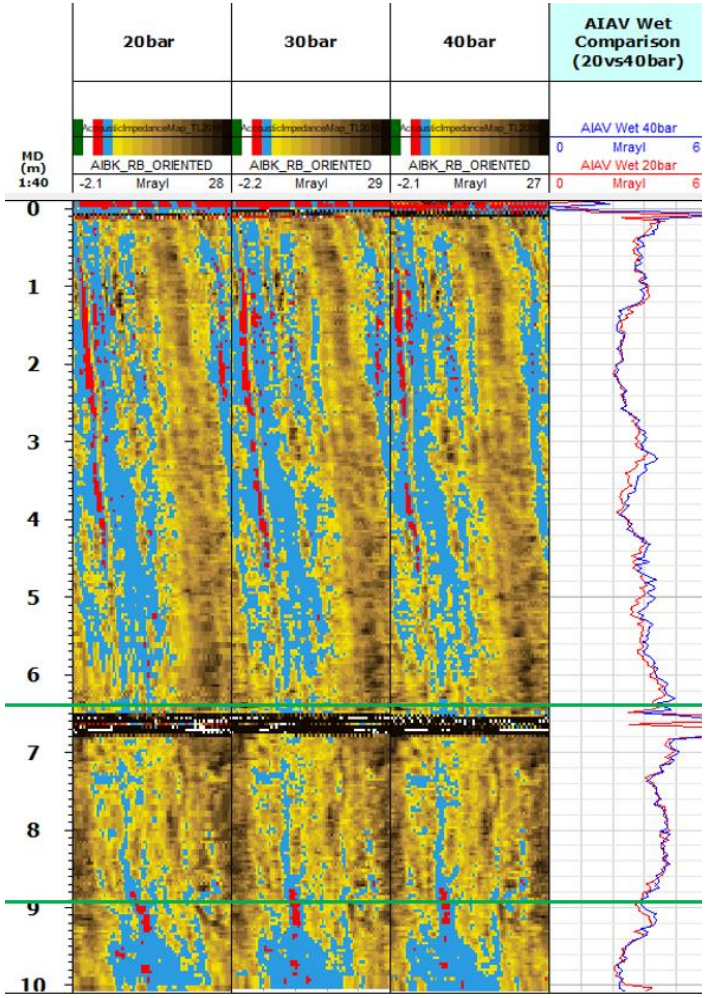


VALHALL DP P&A CAMPAIGN – A15 well

- Two cemented “sandwich” sections (9 5/8 x 13 3/8) retrieved from Valhall A-15 well (drilled in 1985) during P&A campaign and kept for further studies and relogging onshore (NORCE P&A Innovation Program)
  - *Transition joint* (containing TOC, 119 m – 131 m)
  - *Fish #11* (251 m – 263 m)
- Pressure tight bulkheads installed on both joints prior to logging
- Study included acoustic log measurements, annulus leakage tests (water and gas), noise logs, cement core analysis (petrophysical, chemical, mechanical)
- Cement log analysis was then compared with the physical measurements of the well barrier quality

Cement Bond Log Verification

But what does it look like, in real life?



Log results from Fish # 11

Top Fish #11

Bond quality Classification:

Moderate to Poor

Likely Barrier material?

No

Bottom Fish #11

Bond quality Classification:

Moderate to High

Likely Barrier material?

Yes

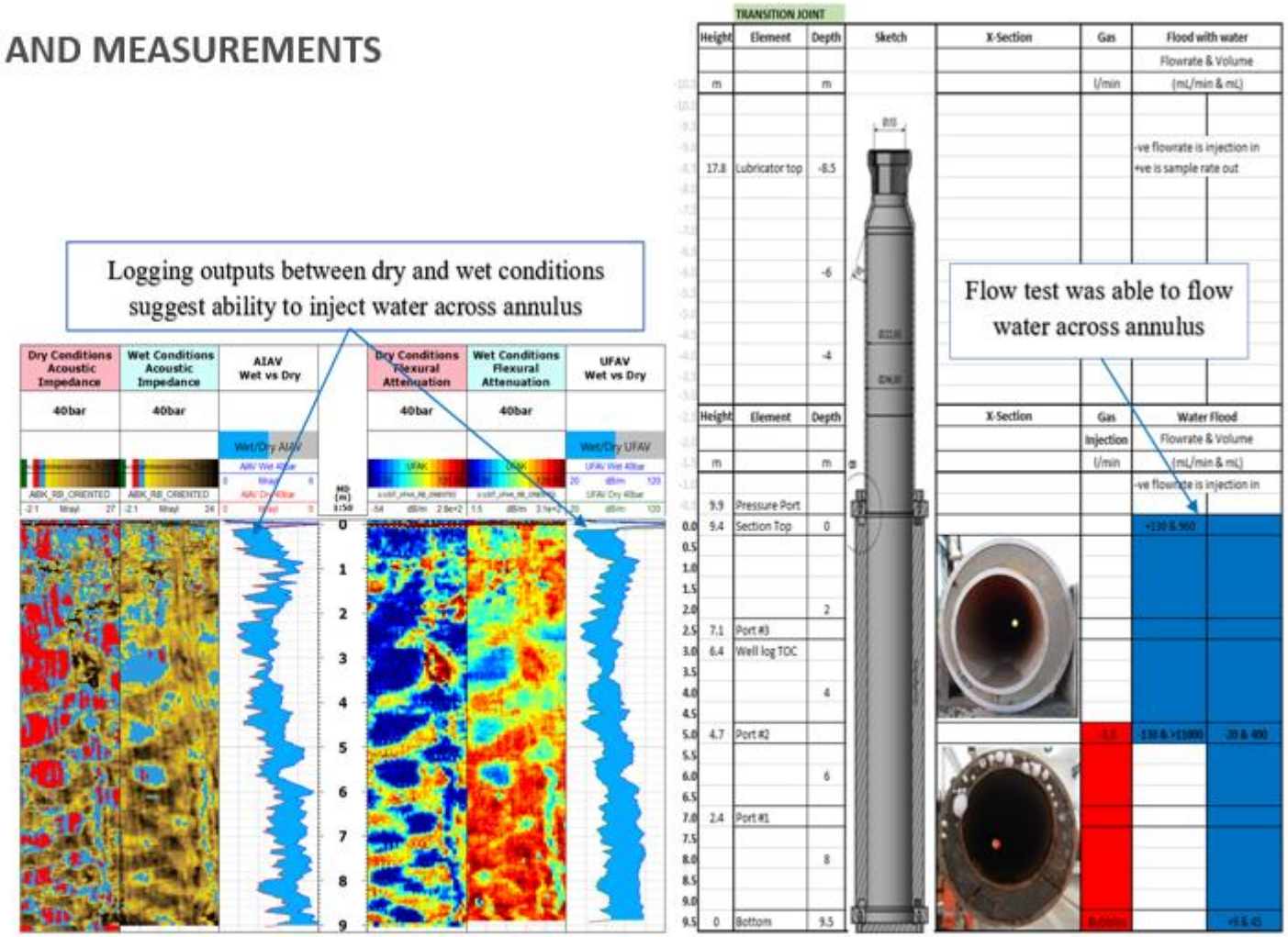
Fish #11 top: 251.67 m

Fish #11 bottom: 263.82 m

Cement Bond Log vs Physical Leakage Measurements (1)

TRANSITION JOINT; COMPARISON OF LOGS AND MEASUREMENTS

- When flooding the annulus, water could be circulated at all five injection points along the length of the section
- This matches the log response before and after water injection which show a significant change of both the acoustic impedance and flexural attenuation

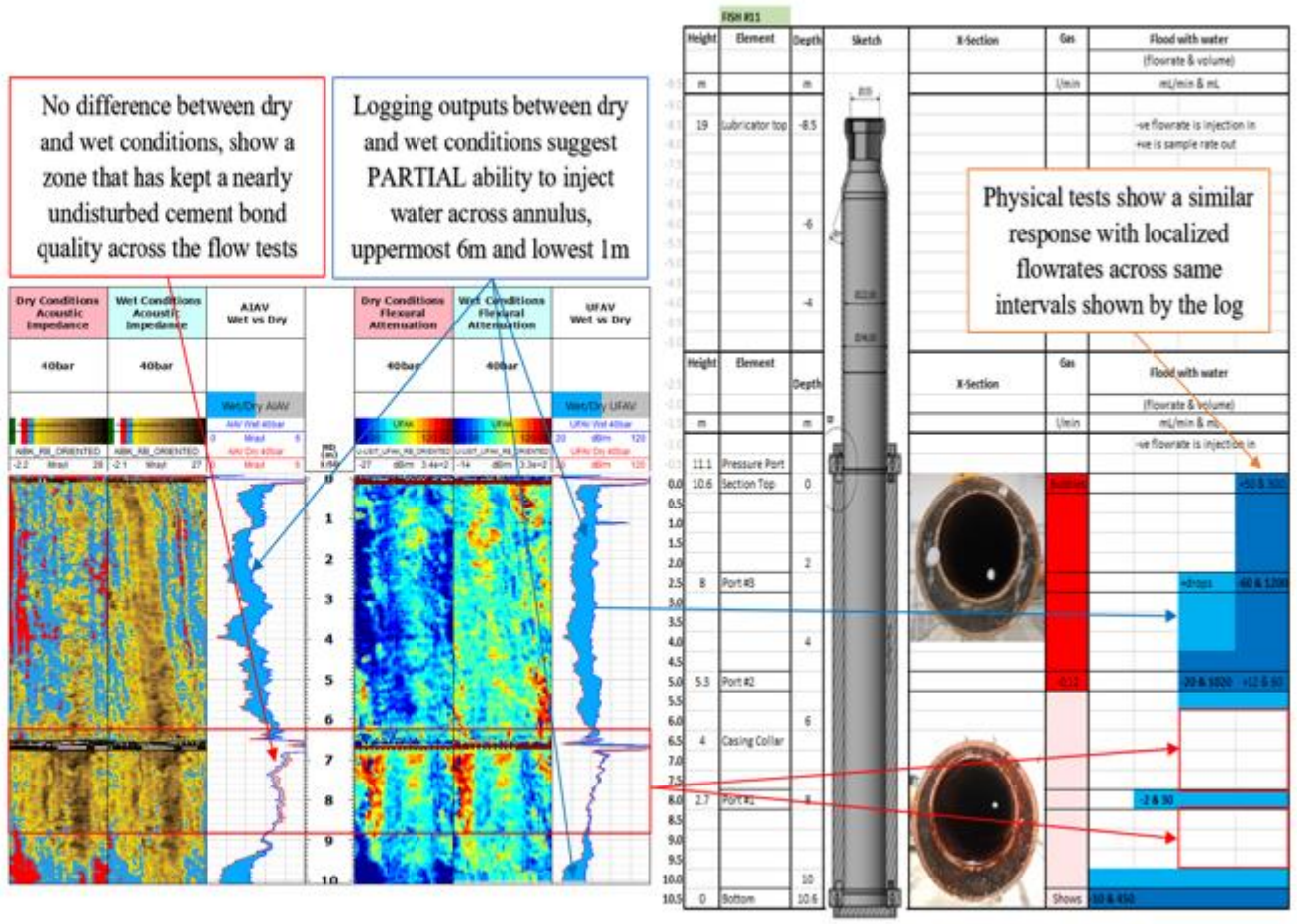


SPE 199609 • An Evaluation of the Cement Sheath Quality of Casing Sections Recovered During a Well Abandonment Operation • Laurent Delabroy

Cement Bond Log vs Physical Leakage Measurements (2)

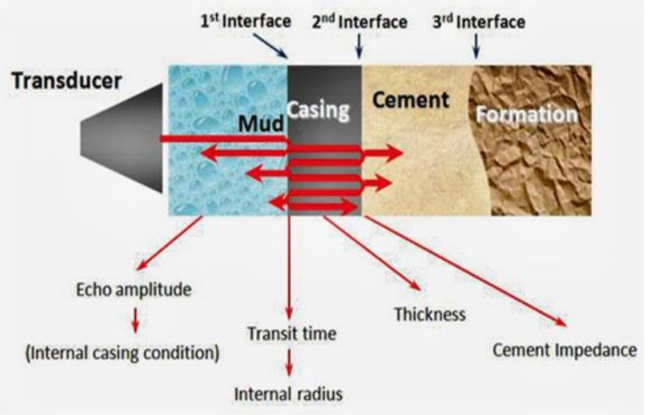
FISH #11; COMPARISON OF LOGS AND MEASUREMENTS

- When flooding the annulus, water could only be circulated through the upper injection ports
- This matches the log response before and after water injection
- No circulation was achieved across the interval from 6 to 9 m where the log response shows well bonded cement



SPE 199609 • An Evaluation of the Cement Sheath Quality of Casing Sections Recovered During a Well Abandonment Operation • Laurent Delabroy

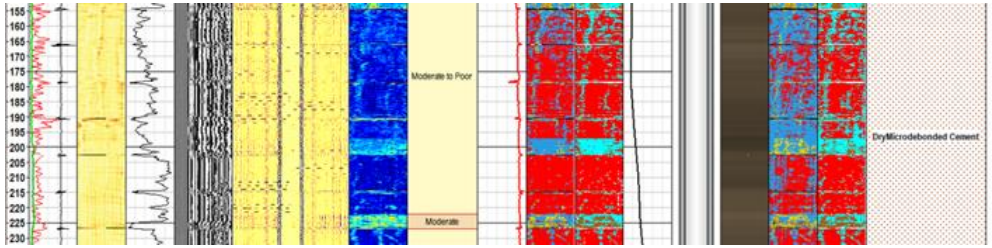
So, Acoustic Logging can be trusted, but…



- Many different acoustic logging tools with various types of measurements and various degrees of circumferential accuracy
  - Acoustic logging is based on acoustic waves propagating in the well. There are two subtypes: Sonic logging is lower-frequency (10–80 kHz) and nondirective, while ultrasonic logging is higher-frequency (0.1–2 MHz) and directive
  - Sonic CBL/VDL
  - Sonic Segmented Bond Tool
  - Ultrasonic Pulse Echo
  - Pitch Catch
  - Wireline vs Drill Pipe

- Can acoustic logging alone suffice to assess zonal isolation in all cases?
  - New multi-physics technology
  - Combination acoustic + ?? (nuclear, noise log etc)
  - Interface cement/formation

- The case of the microannulus
  - Wet / Dry
  - Size?
  - Leakage path?



- Potential artefacts
  - Impact of non-homogeneous mud when logging

- Processing and log interpretation
  - No Standardization for processing (time domain, frequency domain..) nor interpreting log data
  - No standardized criteria for what constitutes a well barrier element based on log measurements

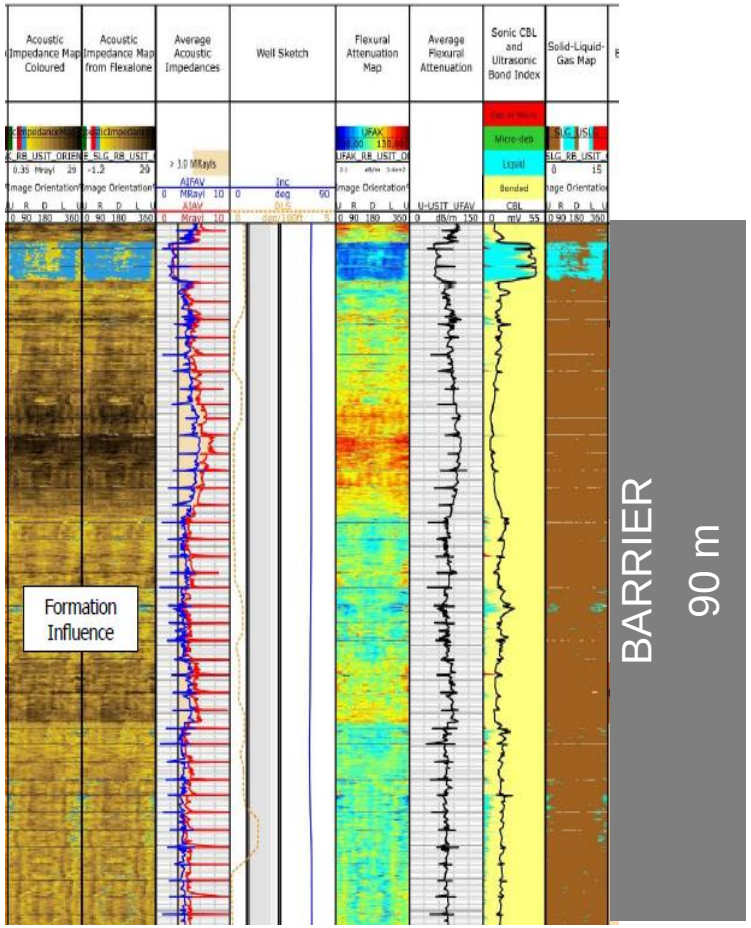
Cement Bond Log Interpretation – lack of standardization

CEM 1A	High	Well Bonded, homogeneous, cement around the entire annulus
CEM 1B	High	Well Bonded, heterogeneous, cement around the entire annulus
CEM 1C	High	Well Bonded, heterogeneous, cement around the entire annulus with non-connected small liquid pockets / short liquid filled channels
CHNCem 2A	Low	Continuous Liquid Filled Channeling — <20% Fluid Channel Width
CHNCem 2B	Low	Continuous Liquid Filled Channeling — 20–40% Fluid Channel Width
CHNCem 2C	Low	Continuous Liquid Filled Channeling — >40% Fluid Channel Width
CONCem 3A	High	Well bonded Cement High Side, Slightly Contaminated Cement Low side
CONCem 3B	Medium	Well bonded Cement High Side, Heavily Contaminated Cement Low side
CONCem 3C	Medium	Homogeneous Contaminated (or Unset) Cement — Lower than expected impedance
PATCem 4A	Medium	Patchy Cement Bond — Medium Isolating potential
PATCem 4B	Low	Patchy Cement Bond — Low Isolating potential
MAWCem 4C	High	Wet Microannulus — High Isolating Potential
MAWCem 4D	Medium	Wet Microannulus — Medium Isolating Potential
MAWCem 4E	Low	Wet Microannulus — Low Isolating Potential
MADCem 4F	Low	Dry Microannulus
GCCem 5	Low	Gas Cut Cement
LLCem 6	Low	Cement in Liner Lap — Eccentralized Liner
FORM 7A	High	Formation Bond Good / Barrier Quality
FORM 7B	Medium	Formation Bond Medium / Not Barrier Quality
FORM 7C	Low	Formation Bond Low / Not Barrier Quality
FORMCEM7C	Low	Combined Cement and Formation Bond — Poor Bond
FORMCEM7D	Medium	Combined Cement and Formation Bond — Medium Bond
FORMCEM7E	High	Combined Cement and Formation Bond — Good Bond — PRESSURE TEST REQUIRED
MUDS 8A	Not applicable	Settled mud solids — High Density / Well Bonded
MUDS 8B	Not applicable	Settled mud solids — Medium Density / Medium Bond
MUDS 8C	Not applicable	Settled mud solids — Low Density / Patchy Bonded
FPL 9A	Not applicable	Liquid Filled Free Pipe
FPG 9B	Not applicable	Gas (or light oil) filled free pipe
OTHER		If the annulus status cannot be classified by one of the above categories
PDQ		Data Quality Issues —such that data is not interpretable

Bond Quality	Bond Quality	General Characteristics
Good	***High***	High Acoustic Impedances (depending on Cement type), Azimuthal solid presence on USIT Acoustic Impedance Images, Low CBL amplitudes, Attenuated Casing Arrivals and Strong Formation Arrivals on the VDL as well as high values for the Flexural Attenuation compared to Free Pipe Zones.
Partial to Good	***High to Moderate***	High Acoustic Impedances and azimuthal solid presence around casing, some small isolated liquid pockets might be present, Low CBL amplitude or (medium amplitude product of a liquid microannulus), formation arrivals might be observed.
Partial	***Moderate***	Scattered Liquid Pockets observed, Average Acoustic Impedances in the medium range (3-4 MRayl, however this will depend on Cement Type), Medium range CBL amplitudes.
Partial to Poor	***Moderate to Poor***	Isolated Liquid Channels and Pockets, Medium to High CBL amplitude (dependent on casing size and cement type), Strong Casing Arrivals, usually low Flexural Attenuation values.
Poor	***Poor***	Continuous Liquid Channels observed, High CBL amplitude close to Free Pipe conditions, Strong Casing Arrivals.
	N/A	Classified as N/A when no cement is expected over an interval (i.e. no Bond Quality to be evaluated as in free pipe zones)

Sources:
Assisted Cement Log Interpretation Using Machine Learning (2023). SPE Drilling & Completion Journal. Link: https://doi.org/10.2118/209529-PA
Assisted Cement Log Interpretation (2022). SPE Norway Subsurface Conference. Link: https://doi.org/10.2118/209529-MS
SLB source: SPE-194172-MS - Cement Interpretation Table

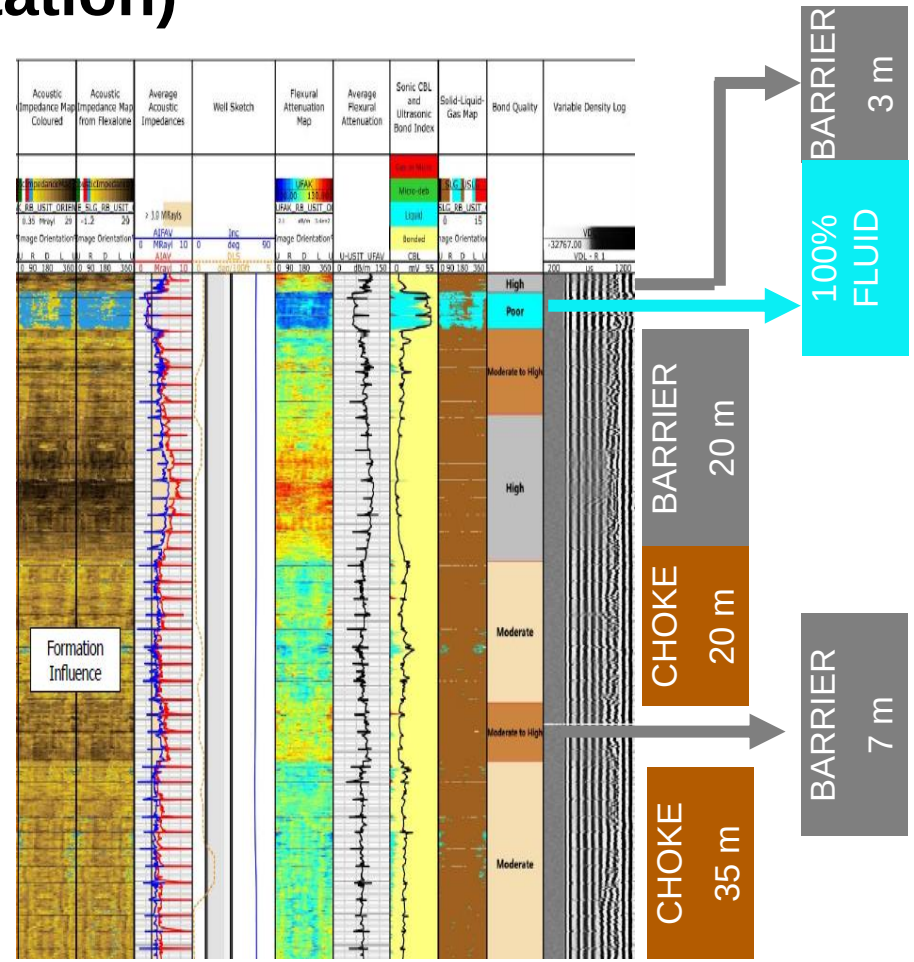
Consequence ? (same log, different interpretation)



«RELAXED» LOGGING CRITERIA FOR BARRIERS AND LOW GRANULARITY

RESULT: «CONTINUOUS» BARRIER INTERVAL & 90m TOTAL BARRIER LENGTH

OR



STRICT LOGGING CRITERIA FOR BARRIERS AND HIGH GRANULARITY

RESULT: «CUMULATIVE» BARRIER INTERVALS & 30m TOTAL BARRIER LENGTH

“Continuous” vs “Cumulative” approach

If the “Cumulative” approach were to be disallowed, what would be the potential consequences?

- Remediation
  - P&A
    - Perf, Wash & Cement
    - Section milling
    - Other
  - Well Construction
    - Sidetrack
    - Re-drill
- Lowering the quality of cement evaluation?
- Deviations
  - Risk of “paper exercise”?

Can we successfully PWC in this situation?

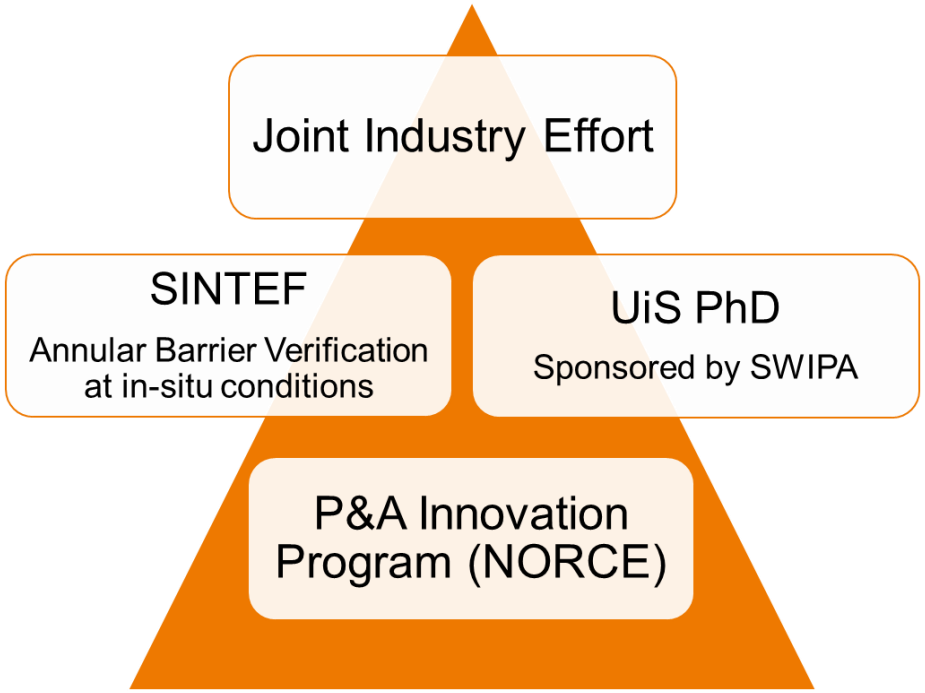
Is the cost of remediating a cumulative interval in order to try to obtain a continuous one a good value proposition?

Well Integrity Forum – “Cumulative vs Continuous” Project Proposition

NORSOK
- Clarifications

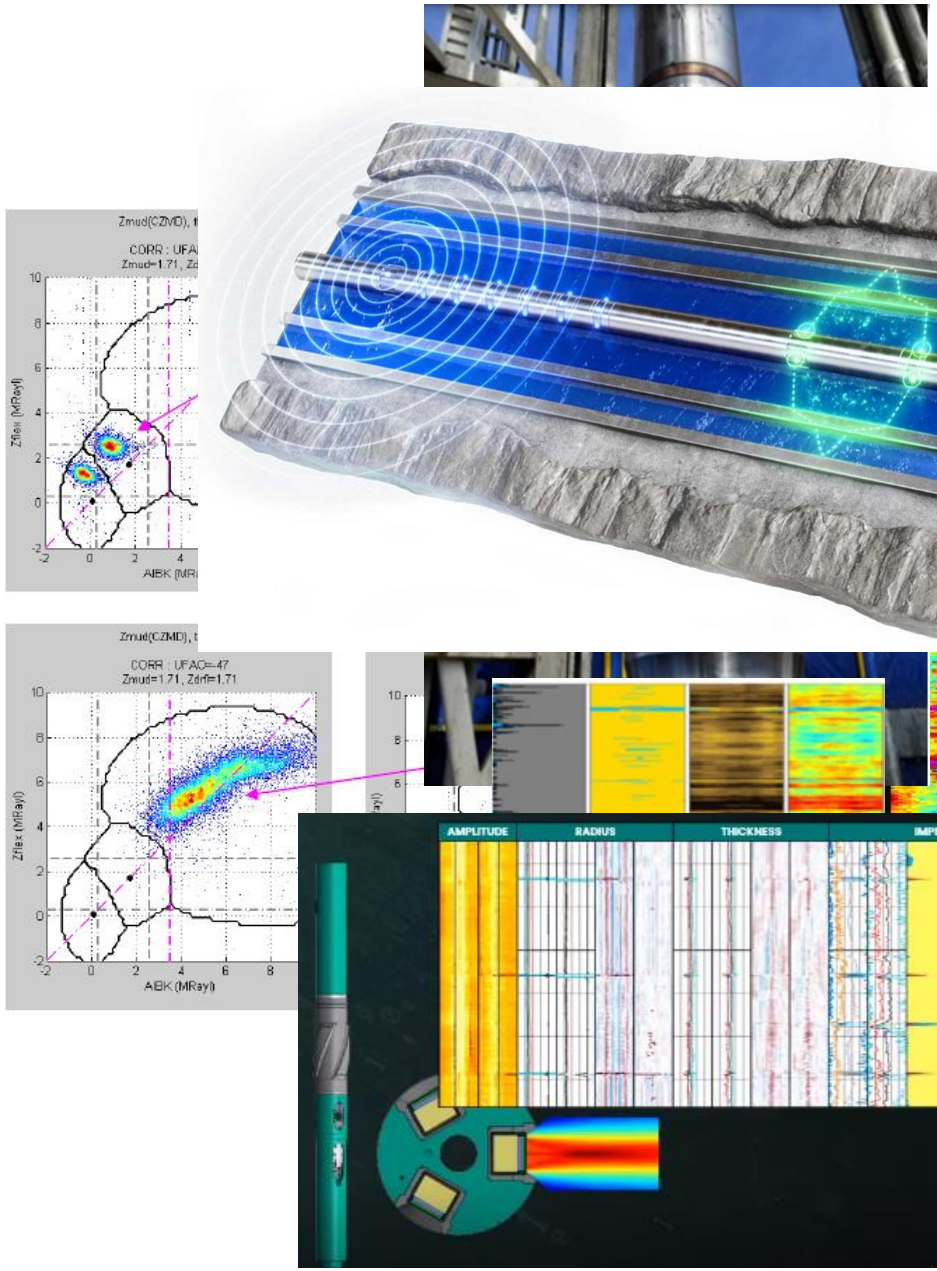
Alignment
- Norwegian regulators
- NCS operators

Technical Report
- Data Interpretation
- Technology

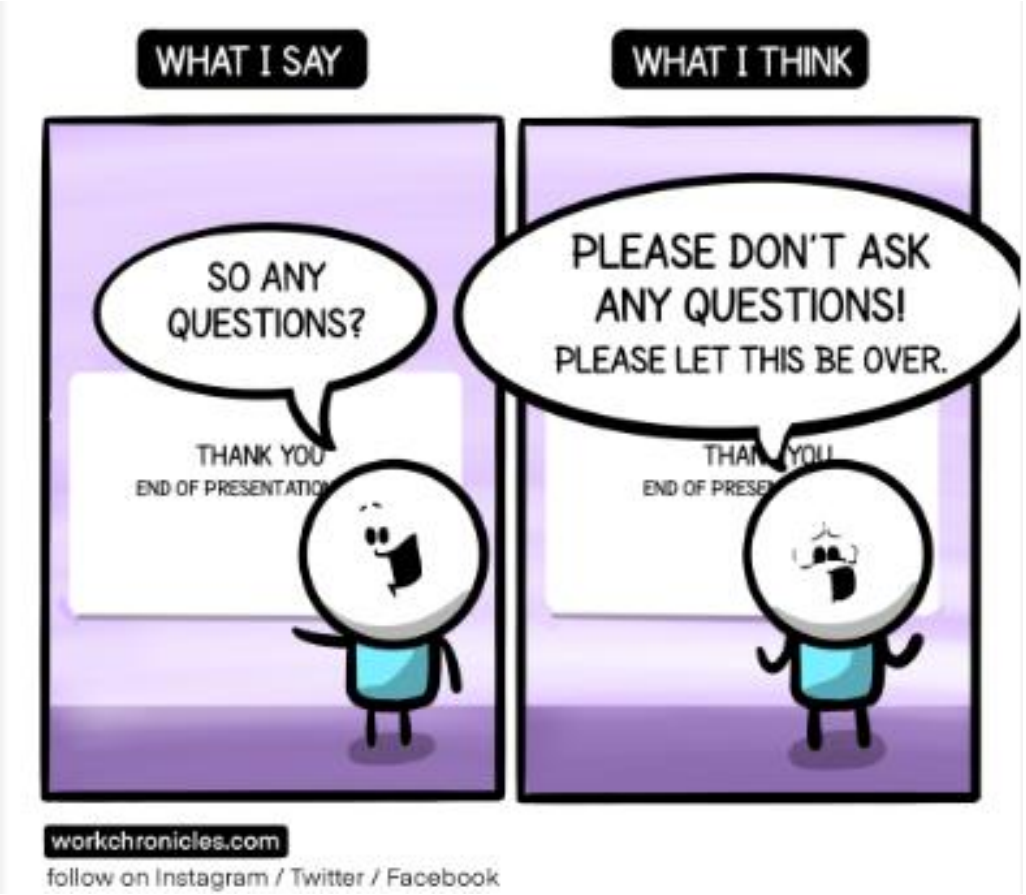


Interesting developments

- Identification of the type of material behind casing: gas, liquid, cement, shale, barite?
- Ultrasonic cement bond logging on Drill Pipe. Wireline no longer required..
- Dual casing / Through-tubing cement bond logging



Q&A


WHAT I SAY
WHAT I THINK
SO ANY QUESTIONS?
THANK YOU
END OF PRESENTATION
PLEASE DON'T ASK ANY QUESTIONS!
PLEASE LET THIS BE OVER.
workchronicles.com
follow on Instagram / Twitter / Facebook

www.akerbp.com