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Improving the understanding, application & reliability of the Perforate, Wash and Cement technique through the use of cement bond logs, tool enhancements and barrier verification via annular pressure monitoring

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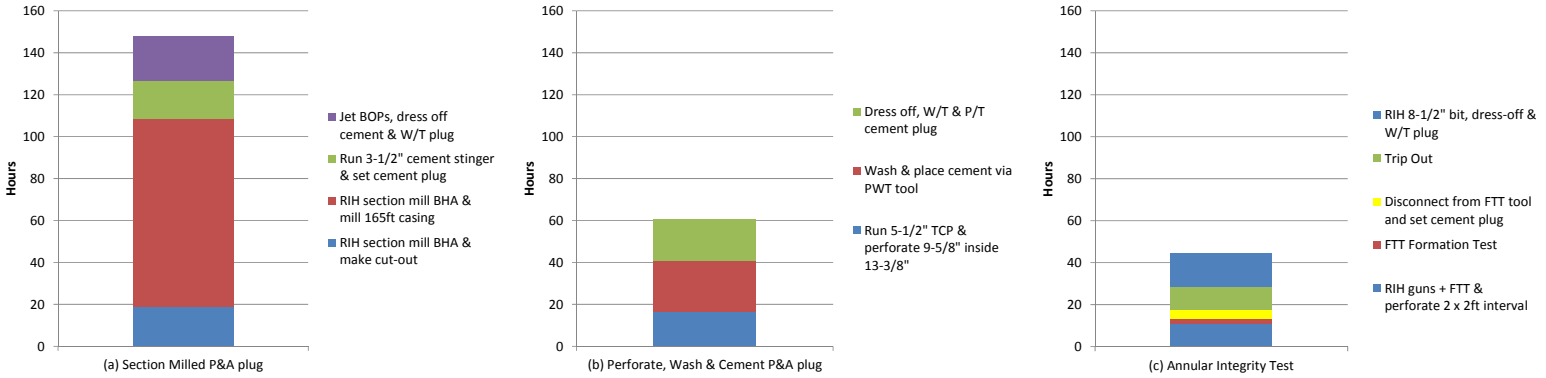
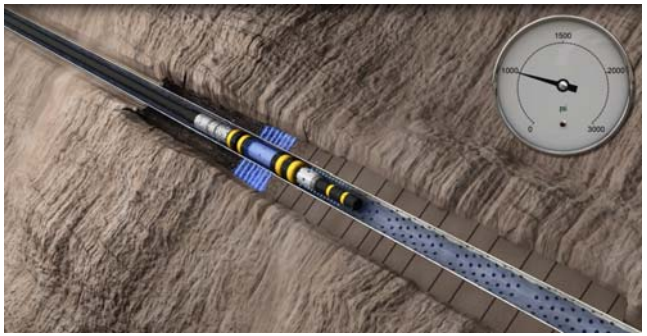
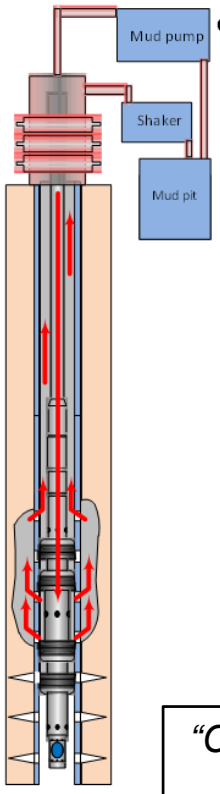
Perforate, Wash & Cement value proposition





Value is eroded if limits not understood and method not correctly applied

Comparison of two methods



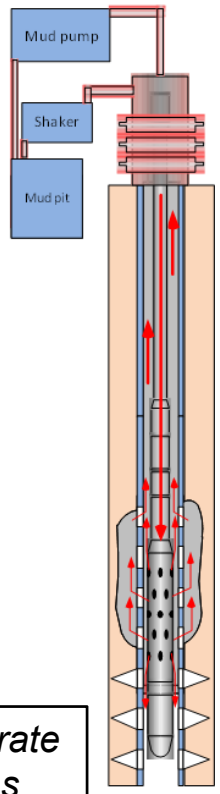
Closed-system Cup Type

1. Has double swab cups above and below nozzles.
2. Washing fluid is 'forced' out of 6 x 0.906in nozzles between swab cups and into annulus via perforations.
3. Fluid has only 1 way to go and has to be forced into the annulus, i.e. is a 'closed system'.
4. Can rotate string above cups by means of a swivel.
5. Cement is forced between cups and into annulus behind perforations.
6. Fluid bipass minimises surge/swab.

1. Due to closed system, standpipe pressure gives continuous *clear feedback signal of washing effectiveness*.
2. Washing data can be used to correlate vs. CBL data and *de-risk chance of washing success*.
3. If annulus is plugged or perforation unsuccessful/blank section, cannot circulate → *tool provides diagnosis*.

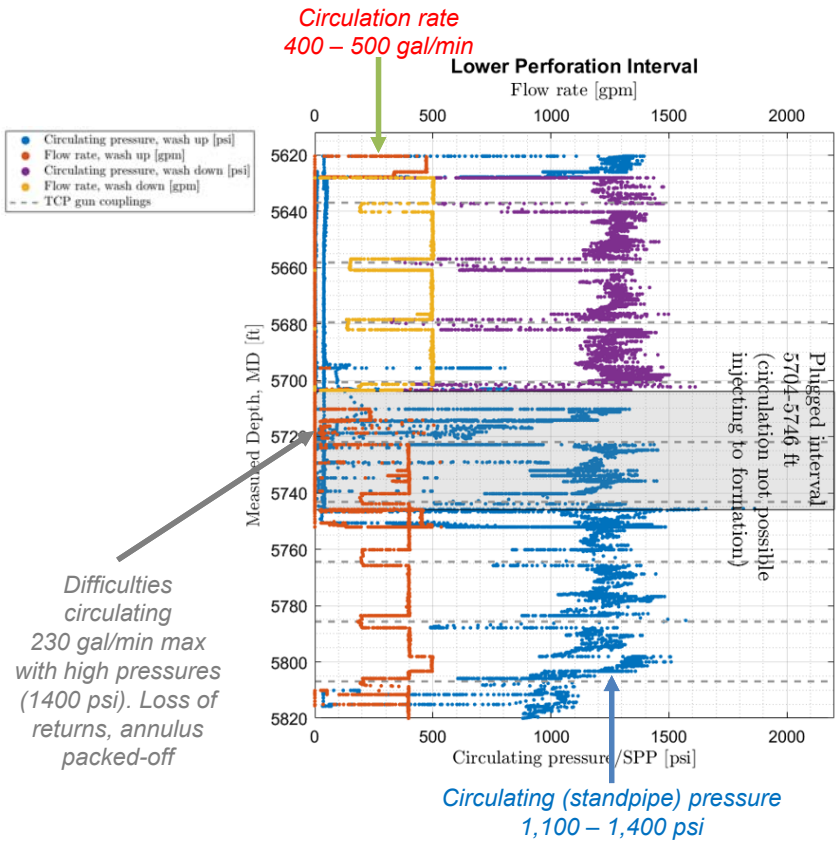
Open-system Jetting Type

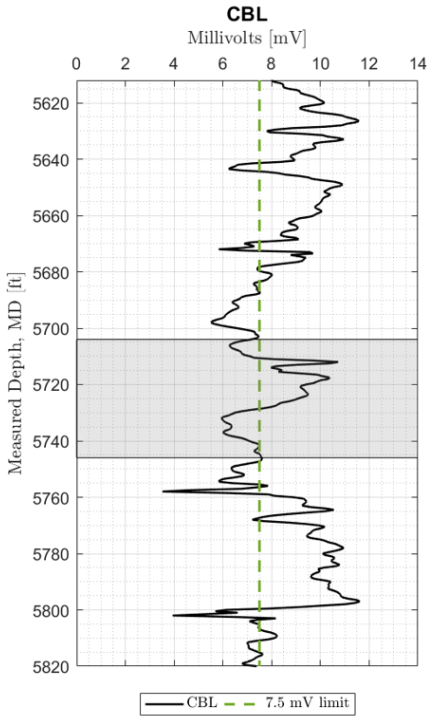
1. Does not require swab cups.
2. Washing fluid is jetted out of e.g. 30 x 1/8in nozzles in a ca. 2.5 ft long sub at high velocity & impact force.
3. Fluid can flow both through perforations to annulus behind and also DP/casing annulus, i.e. is an 'open system'.
4. Can rotate entire BHA at 6 rpm (when over perfs) & 120 rpm (when outside perfs).
5. Cement is sprayed out of nozzles from a ca. 3 ft long cementing valve with 4 x 1/8in nozzles.
6. Cement is pushed in to perforations after spraying using an 'Archimedes' tool.
7. 18 spf with 1.1in EH or greater preferred



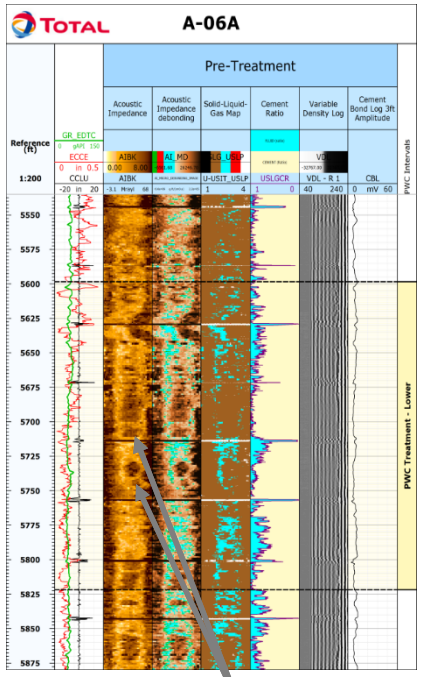
"Cup Type" tool provides standpipe pressure and flow rate signals which can be correlated to annular conditions

Initial field observations I (workover lower zone)





CBL never above 12mV
(free pipe 57mV)



Dark patches on AI from 5,705 – 5,746 ft suggesting formation contact with casing corresponded with circulation difficulties

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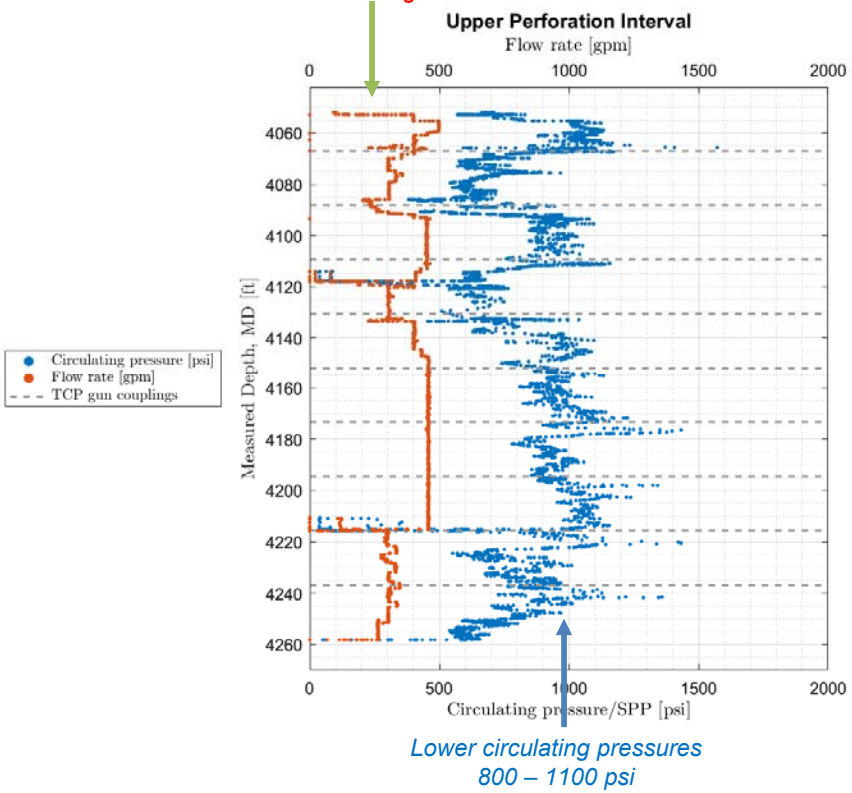
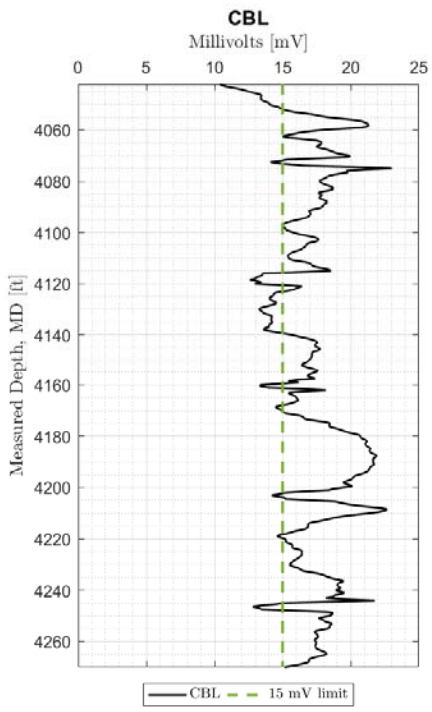
Initial Field Observations II (workover upper zone)

Consistent circulation at 400 – 500 gal/min

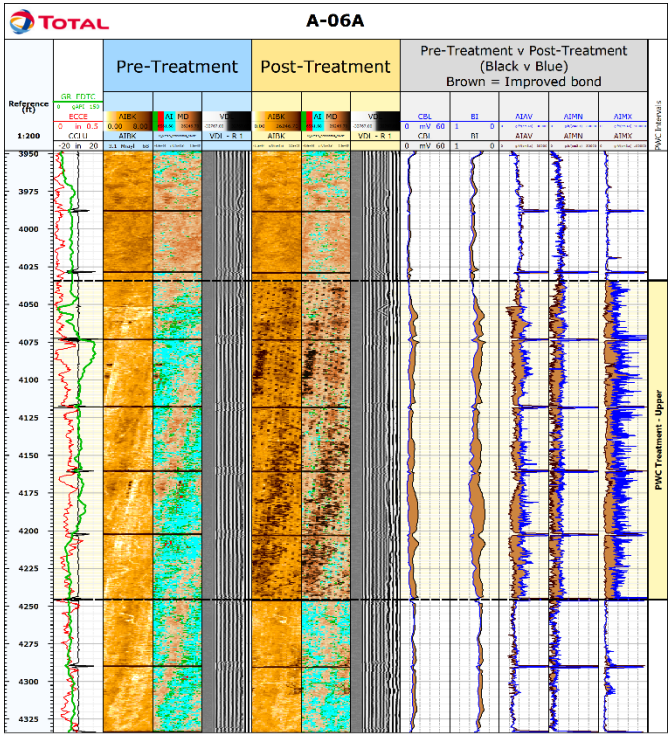


Lower circulating pressures 800 – 1100 psi

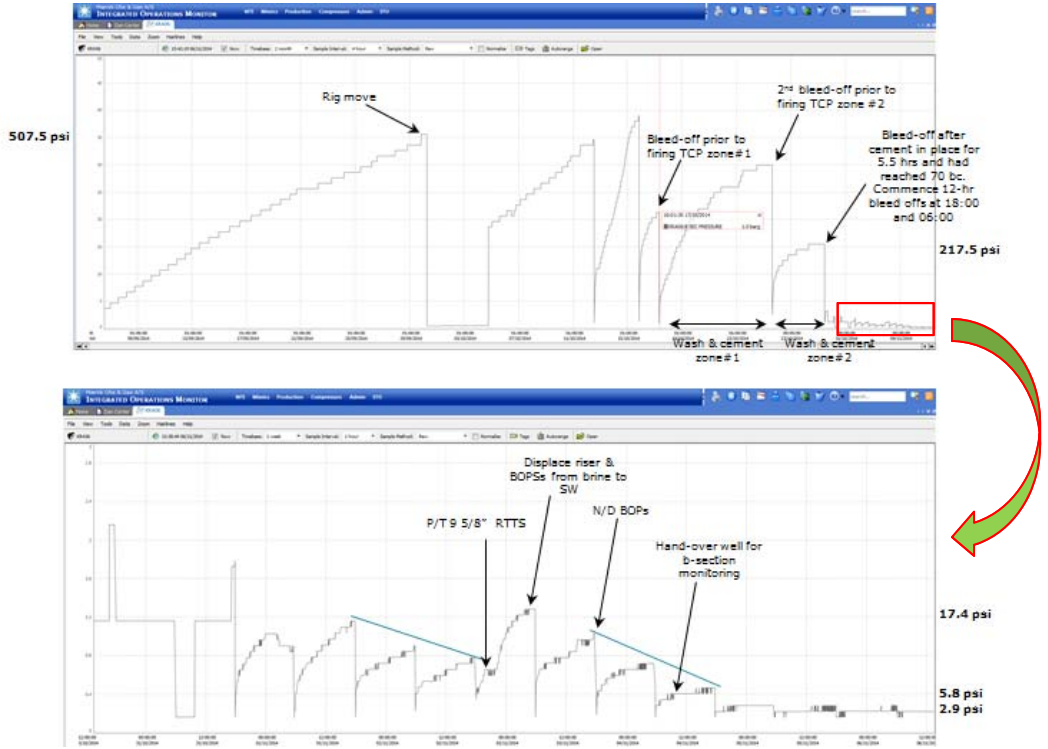


CBL never lower than 12.5mV and generally above 15mV

Verification by bond log and SCP monitoring

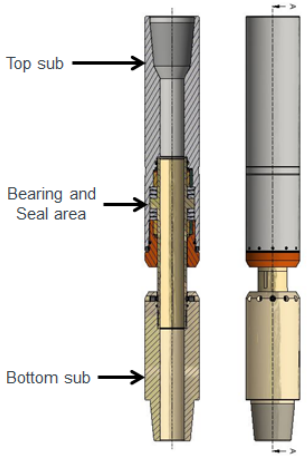


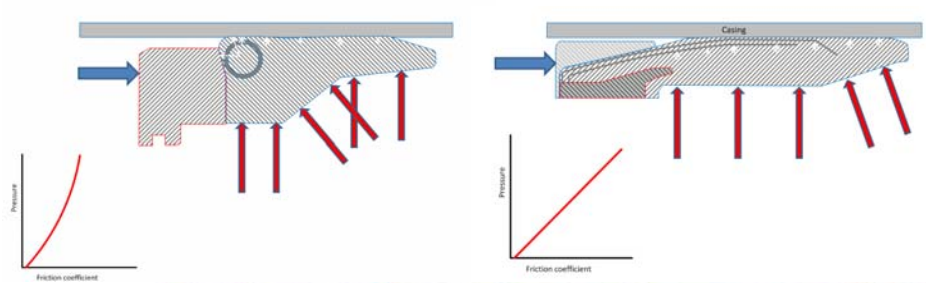
CBL dropped, bond index, impedance, attenuation min & max all increased indicating improved bond



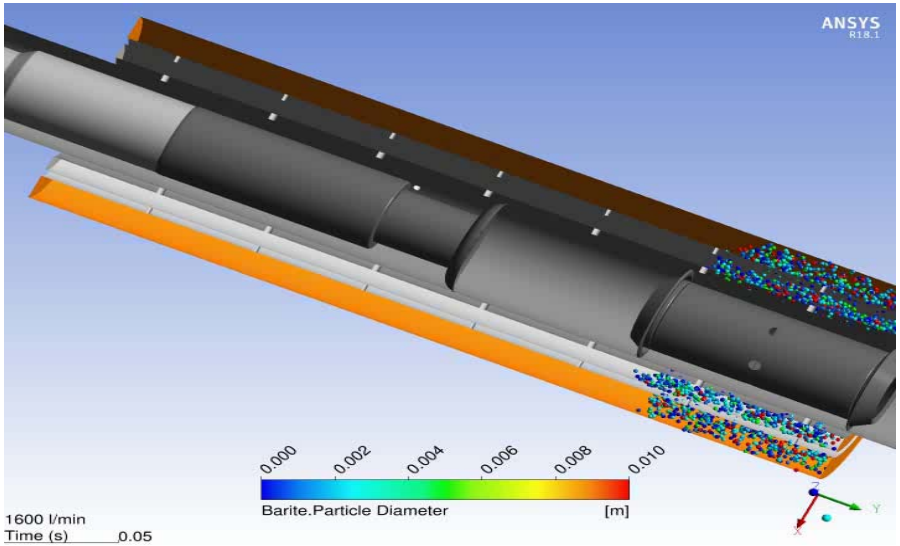
B-annulus bled off every ~24 hrs following curing of cement: static at 2.9 psi and monitored for ~4 weeks prior to drill-out, tieback casing and upper completion installation

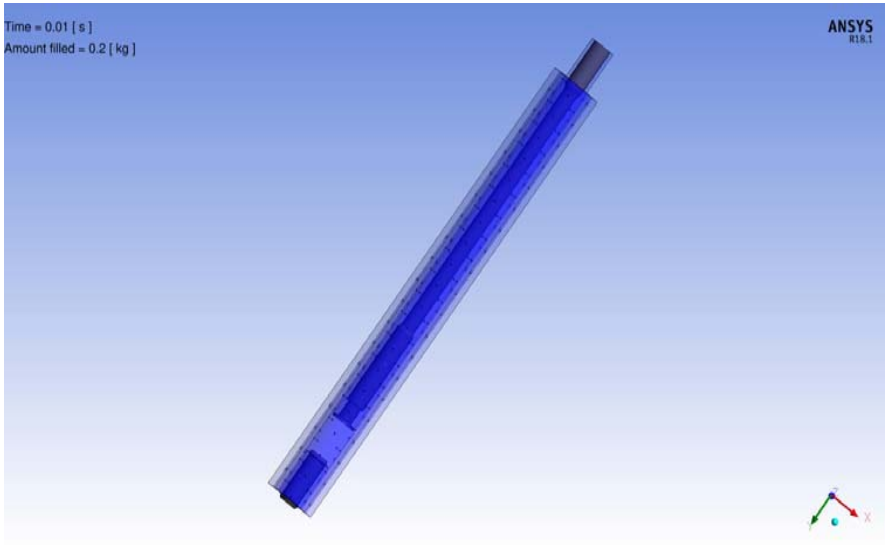
Tool enhancements





CFD analysis & yard tests for method verification





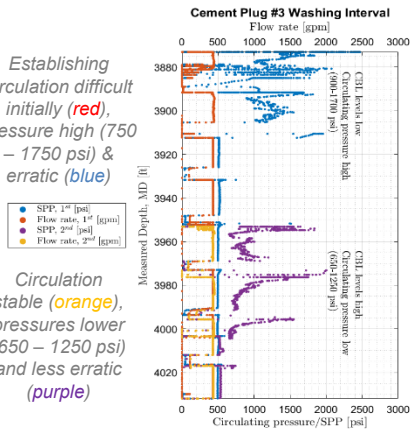
Yard test concept verification

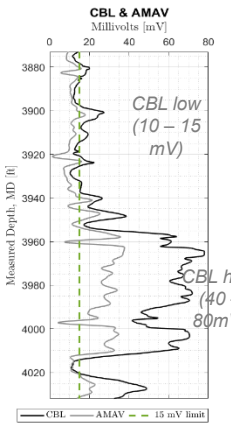



Application to campaigns I (abandonment lower & upper zone)

Establishing circulation difficult initially (red), pressure high (750 – 1750 psi) & erratic (blue)

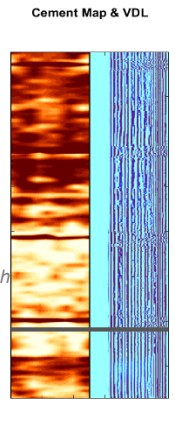
Circulation stable (orange), pressures lower (650 – 1250 psi) and less erratic (purple)



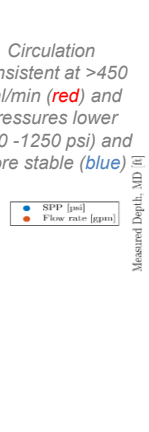


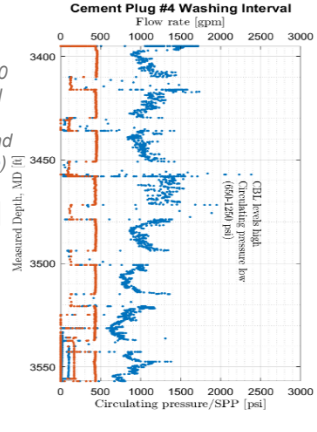
CBL low (10 – 15 mV)

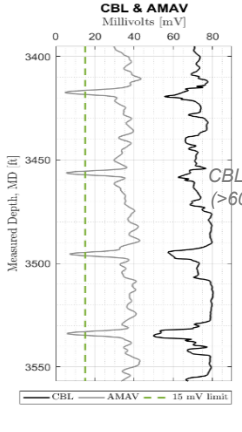
CBL high (40 – 80mV)



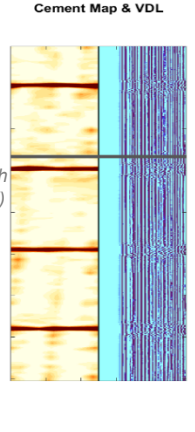
Circulation consistent at >450 gal/min (red) and pressures lower (650 -1250 psi) and more stable (blue)

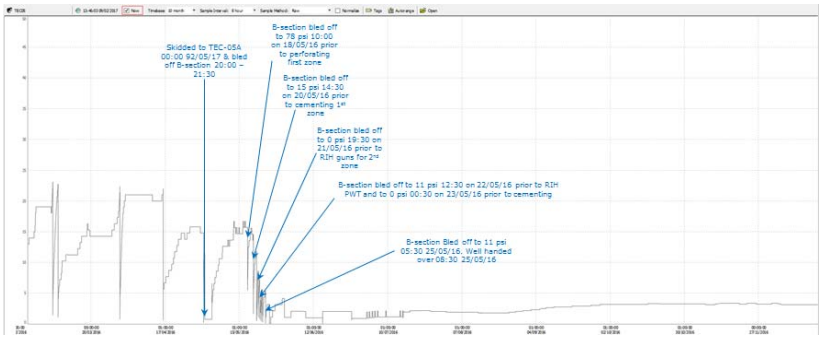






CBL high (>60mV)



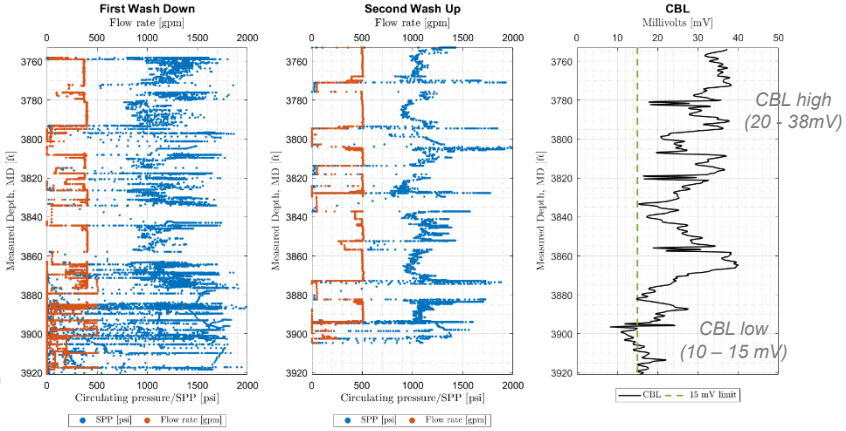


B-annulus static (>6 months of data shown)

Application to campaigns II (workover)

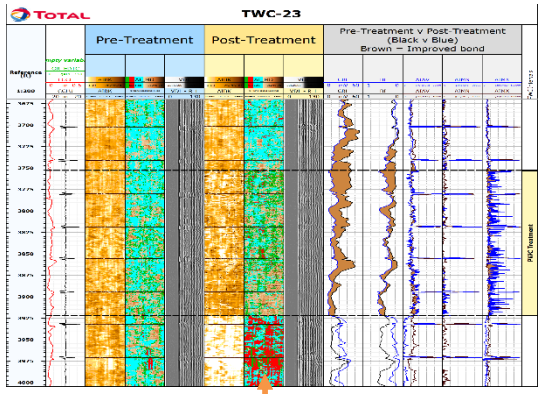
Circulation at 400 gal/min (red), pressure 1000 – 1400 psi) (blue)

Circulation harder to establish, reduced to 50 – 350 gal/min (red),persistent high pressure spikes (blue)



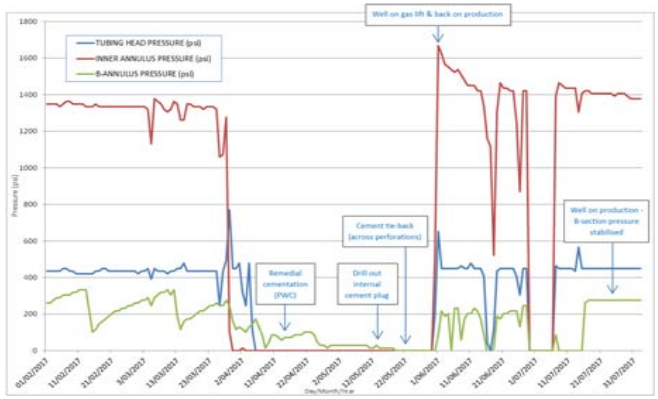
CBL high (20 - 38mV)

CBL low (10 – 15 mV)



CBL dropped, bond index increased.

Note gas build-up below remediated annulus (red)



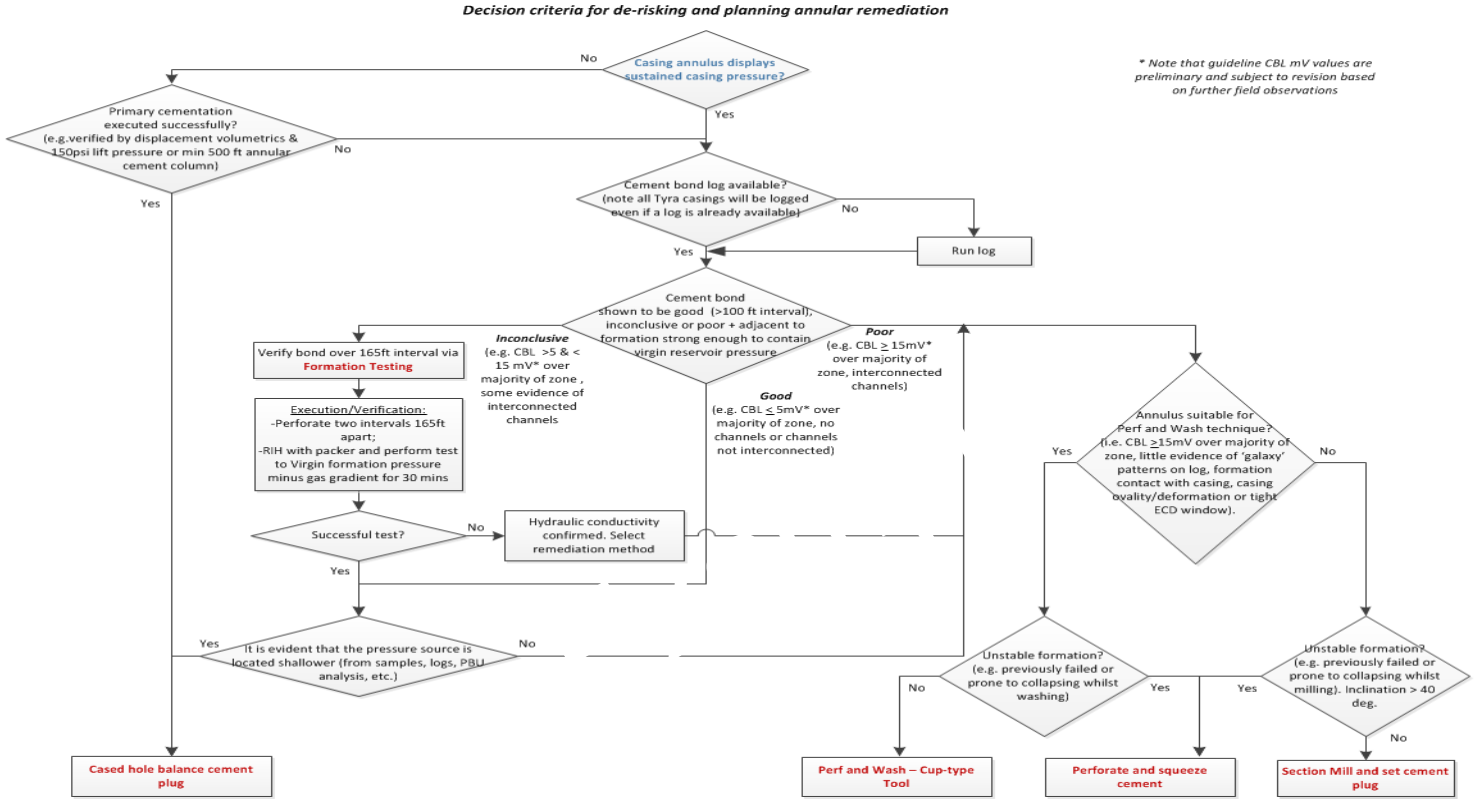
Well on production, B-annulus static

Summary table

Casing size	Bond quality	Degree of hydraulic isolation	Circulation potential	CBL mV ('average bond') free pipe level	CBL mV	AMAV mV	VDL ('near casing' and 'cement to formation' bond)	Attenuation dB/ft	Comment
9-5/8"	Good bond	Hydraulically isolated	Circulation not possible	57.415[1]	≤5	≤CBL[2]	No casing arrivals, presence of clear formation arrivals	Above free pipe level[3]	Clear and consistent circumferential bond. Absence of channeling or discontinuous channeling.
	Intermediate bond	Not hydraulically isolated, some communication possible	Circulation difficult	57.415[1]	6-14	≥10 and ≥ CBL[2]	No/faint casing arrivals. No/faint evidence of formation arrivals	At or 'just above' free pipe level[3]	Presence of channeling. May be discontinuous. Ability to circulate may be improved by re-perforating.
	Poor bond	Not hydraulically isolated, full communication	Circulation possible	57.415[1]	≥15	≥15[2]	Clear and solid casing arrivals visible.	Below free pipe level: 9 5/8" #40 1.6 dB/ft 9 5/8" #47 2.6 dB/ft 9 5/8" #53.5 3.8 dB/ft	Presence of clear and continuous channeling for circulation.

[1]: Free pipe levels provided by logging tool vendor.
[2]: AMAV levels are highly provisional and further investigation is required to better determine the cut-off levels shown.
[3]: Attenuation free pipe levels are casing weight dependent. Further investigation is required to better determine attenuation level cut-offs for intermediate and good bonds.

Decision Tree



Conclusions

1. Closed-system ”Cup-type” tool ensures direct communication with the annulus & standpipe pressure gives a clear indication of degree of bond and washing effectiveness.
2. Washing parameters can be used to correlate against logging responses and is of great utility in planning & selecting the best zones for remediation.
3. CFD & Yard Testing and 120 field runs confirms ”Cup-type” tool as effective.
4. Field observations show that when the method is correctly applied according to the operational limits defined here, job can be de-risked allowing:
    a. Correct identification of the ability to circulate in 94% of cases
    b. Effective remediation of annuli: SCP remediated in every case at point of well handover
5. Track-record of successful remediation vs. logging & washing parameters across >10 fields across in the North Sea qualifies the method as robust.

Acknowledgements / Thank You / Questions

Learn more at the Archer Booth

Total

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