



P 030

Use of Pulsed Neutron Logs to Detect Tubing Leaks and to Identify Water Channeling behind Casing - Case Studies from Western Offshore Fields

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Summary

Well integrity issues have always been a matter of great concern for oil industry worldwide. Life of a well can be affected by deterioration of the casing/tubing integrity which can be due to corrosion or mechanical damage during drilling/work over resulting in channelling of fluids. Remedial measures can be executed if the nature of problem is diagnosed.

One can receive early warning of a potential problem and obtain data for determining a specific restoration program by running Pulsed Neutron Logs in Water Flow mode and map flow of water behind or inside pipe. Combining WFL measurements with Production Logging provides unknown answers of well integrity.

Present paper contains case histories of two Injectors in a field of Western Offshore, where Water Flow Logs (WFL) were recorded alongwith Production Logging to identify the cause of pressure build-up in the tubing-casing annulus. Completion issues like casing damage, tubing and packer leaks were confirmed from WFL.

WFL and Production Logging were also carried out in one of the gas wells of Western Offshore, to locate the source of water. It emerged from WFL survey that the produced water was channelling up behind casing and entering the well bore through bottom of perforations.

Keywords: Water Flow Log -WFL, Mechanical Plug Back Tool- MPBT, Pulsed Neutron Tool-PNT

Introduction

Water flow mode of Pulsed Neutron Logs works on the principle of oxygen activation of flowing water slug. Quantitative velocity measurement along with direction of slug movement helps in the identification of damaged parts of the pipe and possible thief zones. A stationary measurement is done by parking the tool and keeping it centralized to the wellbore. The nominal velocity range for WFL is 20-300 ft/min. The total range using all three detectors (near, far and GR tool) becomes 2-500 ft/min. Water velocities can be computed from the station measurements with sensitivity down to ~2-4 ft/min. with near detector and higher sensitivities with other detectors.

Water Flow Log Measurements

The heart of Pulsed Neutron Tool (PNT) is a minitron which is essentially a ceramic tube containing tritium and deuterium at low pressure. **(Fig-1)** This device generates neutrons at a constantly regulated energy level of 14 MeV by accelerating deuterium ions into a tritium target.

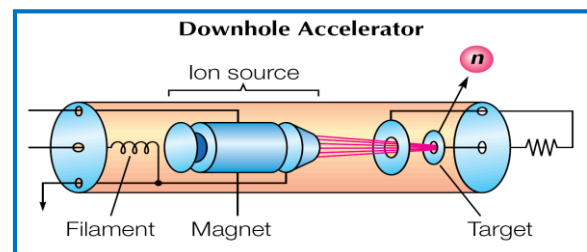


Fig-1: Minitron



In Water Flow Log mode, the minitron carries out one burst and is then off for a longer period. Each detector records the gamma ray counts vs. time in the oxygen energy window. The minitron activates the oxygen in the water and, when the activated oxygen flows across the detector, the detector records the GR peak rate. **(Fig-II)**

Knowing the distance from minitron to a specific detector and the elapsed time between neutron burst and the peak in GR count rate, the velocity of the water can be calculated. Data can be recorded in three modes Short, Normal and Fast and Neutron Burst timings decides the mode.

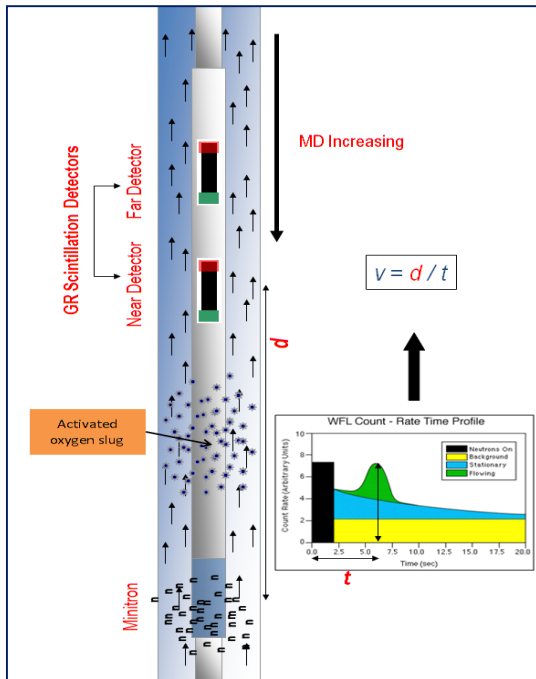


Fig-II: Theory of Water Flow Log

Normally the tool is run with just the near and far detectors but for high flow rates another detector can be added downstream. At the bottom of the slide the nuclear reactions are shown in detail. **(Fig-III)** The complete sequence from activation to the emission of a GR has a half life of approximately 7 seconds.

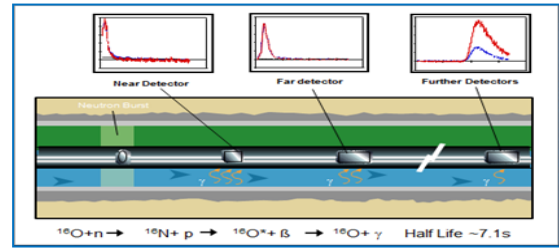


Fig-III: Detector signal -Water moving from left to right

Case Studies

Well "A"

Well "A" is a deviated water injector with maximum deviation of 90 degrees. This well was completed with 7" liner and 3.5" tubing in the upper segment and further extended into 6" drain hole (X332-X434 m) for water injection.

Tubing and Packer leakage were suspected so Production Logging survey was carried out in May 2012, inside 3.5" tubing and 7" casing sections using turbine spinners in PSP tool string in order to determine injection profile.

PLT Injection profiling indicated that whereas in 3-1/2" tubing injected water velocity was about 366 ft/min. (~ 3000 BPD), but in 7" liner section, just below tubing shoe spinner response is almost negligible. This suggested that hardly any water is being injected in the open hole section below 7"liner and probably injected water is going somewhere else. It was thought that the Packer was leaking and entire injected water was flowing upward into the annulus of 3-1/2" tubing and 7"liner.

So, it was decided to record Water Flow Logs to monitor the flow response of injected water in annular region of tubing and casing.

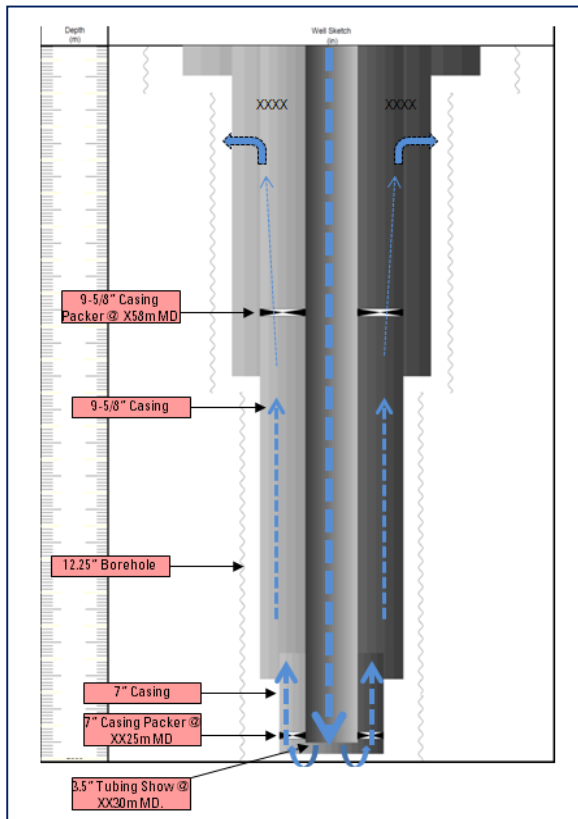


Fig-IV: Schematic of Water movement inside tubing and in annulus of casing and tubing

Water Flow Survey was carried out and it was found that water is flowing up @ 70 ft/min, both below and above 7” Packer in the annular region of 7” liner and 3-1/2” tubing, confirming that Lower Packer in 7” casing at X225m is leaking.

Further, it was also observed that Upper Packer in 9-5/8” casing at X59m is also leaking, as water was flowing up at 39 ft/min above this packer. However, no upward water movement was found above X62m, thereby indicating that injected water was going in the formation at X62m.

(Fig-IV). A temperature anomaly was also observed indicating anomalous movement of water around X62m.**(Fig-V)**

Water Flow Survey clearly established that both the packers in 7” liner and 9-5/8” casing were leaking, besides, it also emerged that there is some damage in 9-5/8” casing at around X62m through which injection water is escaping outside.

Thus, WFL could detect channelling up of water in annulus of tubing and casing even under conditions when water was simultaneously moving down in tubings during course of injection.

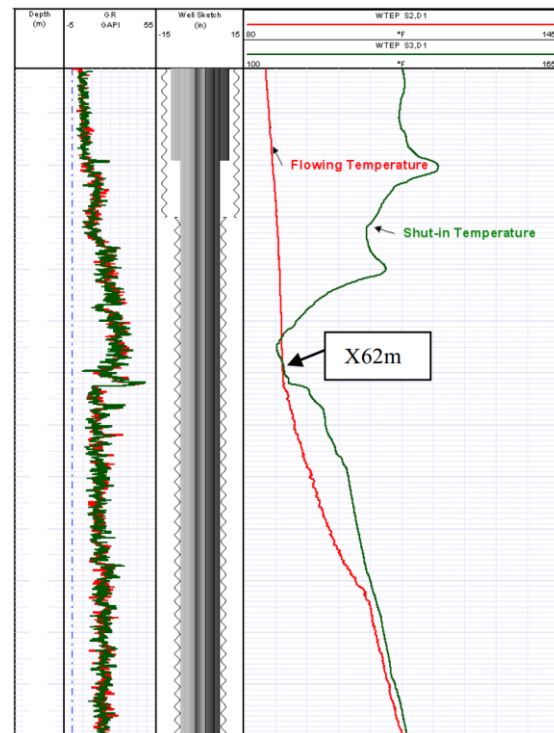


Fig-V: Temperature anomaly at X62m

Well “B”

Well “B” an injector having deviation of 51.25 degrees and completed in the interval X056-X068m, faced annulus pressure build up problem during water injection. The well was completed with 3-1/2” tubing and 9-5/8” casing.

In order to diagnose the problem, a Production Logging survey was done in May 2012, in two different runs. Production Logging was done in Run-1 as per following sequence:

1. Annulus was kept shut and injection was done in tubing while recording production log.
2. Annulus was bled-off while recording PLT and few WFL stations near the packer.



Injection Flow rate quantification showed that amount of water flowing near tubing shoe was same as that flowing inside casing which suggested that water was not flowing upward via any packer leak.

When Annulus was shut, it was found that bottom 2.0 m (X066.0–X068.0 m) of the perforation (X056.0–X068.0m) is taking 4049 BWPD. After annulus pressure was bled off, it was found that 2.0m (X066.0–X068.0m) of the perforation (X056.0–X068.0m) is taking 3864 BWPD. **(Fig-VI)** The difference of 185 BWPD in the two injection runs is because of 21 psi difference in injection pressure. Further, even temperature response in these cases could not provide any clue of tubing leak. So, the cause of annulus pressure build-up could not be evaluated.

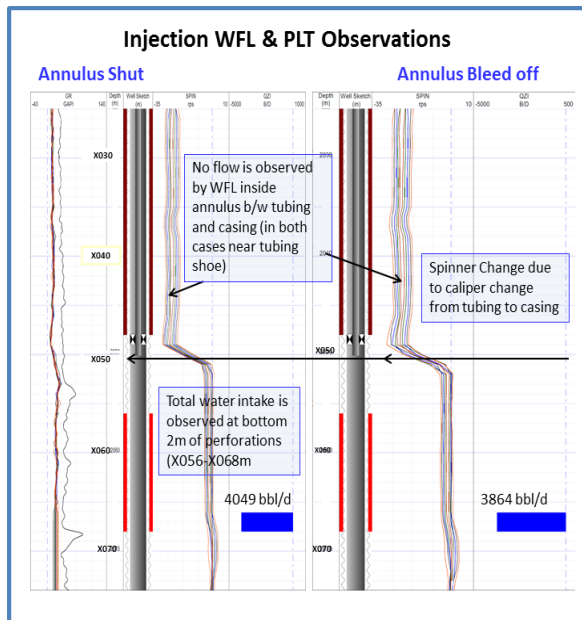


Fig-VI: Production Logging Results

In order to further investigate the reason behind annulus pressure build up, Run-2 campaign of Production Logging along with Water Flow survey was designed as per the following recording sequence:

1. Baseline PLT survey from surface till bottom .
2. PLT survey from surface till bottom while injecting water through tubing and keeping annulus shut.

3. PLT survey from surface till bottom while injecting water through tubing and bleeding off annulus pressure.
4. PLT survey from surface till bottom while injecting water through annulus and producing from tubing.
5. RST WFL survey from bottom of the well till surface.

When the well was shut, consistent spinner indicated no activity. **(Fig-VII)**

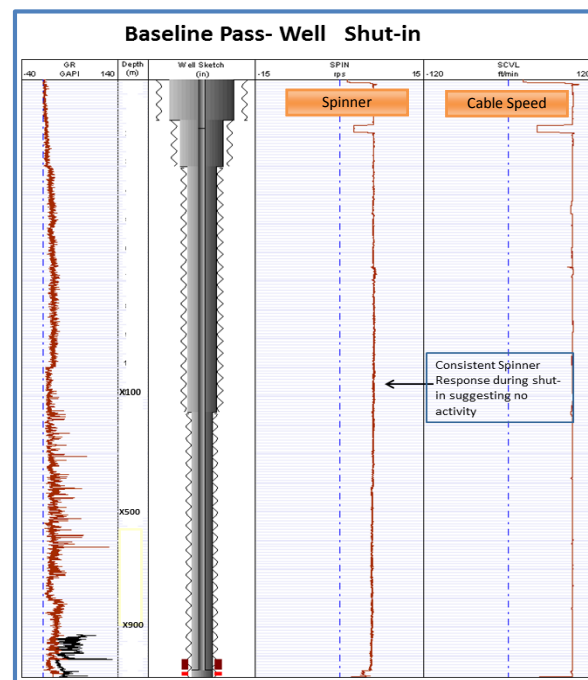


Fig-VII: Base PLT observations during well shut-in

When annulus was shut and water was injected in tubing spinner activity was seen suggesting water entry into the annulus. **(Fig-VIII)**

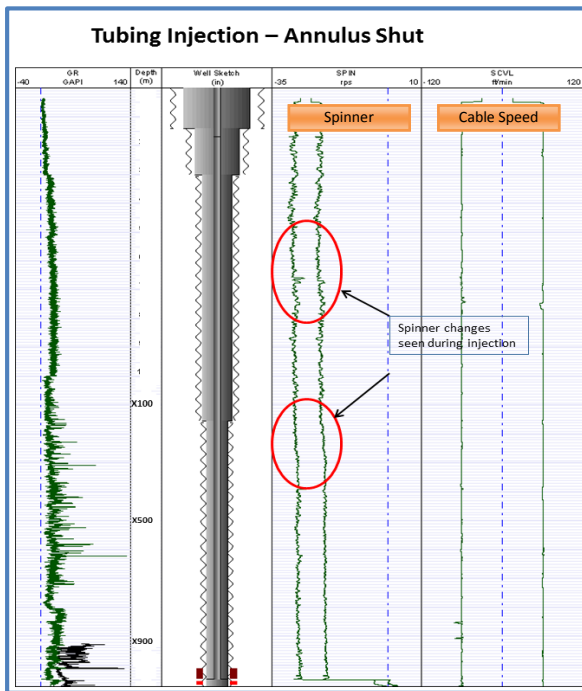


Fig-VIII: Injection through tubing and annulus shut-in

When annulus was bled-off and water was injected in tubing, similar spinner changes were observed. (Fig-IX)

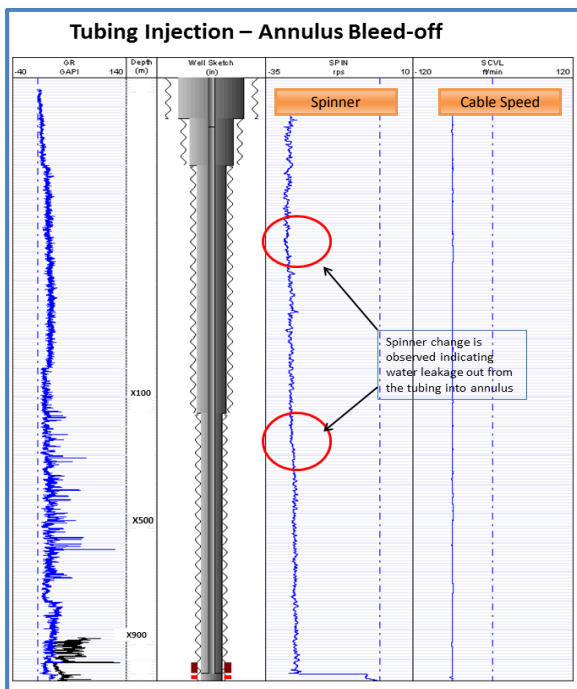


Fig-IX: Injection through tubing and annulus Bleed-off

When injection was carried out through annulus and production taken from tubing tubing leaks were detected at several depths both by spinner and WFL stations. (Figs-X)

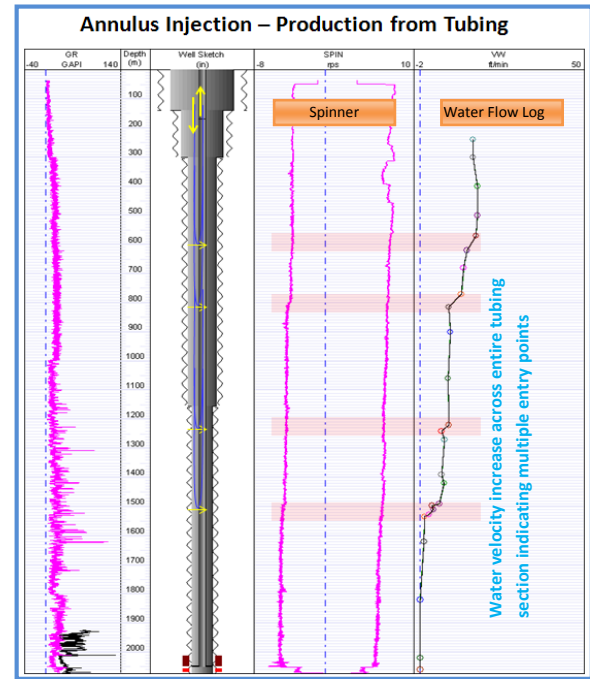


Fig-X: Water Flow Survey and spinner response during injection of water through annulus-showing tubing leaks

SL No.	Depth (m MD)	Water Velocity (ft/min)
1	X 060	0.0
2	X 020	0.0
3	X 820	0.0
4	X 620	1.1
5	X 534	1.3
6	X 527	2.7
7	X 510	4.0
8	X 497	3.6
9	X 490	5.8
10	X 420	7.2
11	X 390	6.5
12	X 270	7.4
13	X 240	6.5
14	X 220	8.7
15	X 060	8.5
16	Y 14	8.7
17	Y 70	12.5
18	Y 80	13.2
19	Y 20	14.3
20	Y 70	17.0
21	Z 40	16.1

Fig-XI: Summary of WFL Stations



Positive spinner changes were observed inside tubing at several depths, indicating entry of water through suspected tubing leaks (**Fig-X**).

Summary of WFL stations in **Fig-XI**, indicates that at a depth of X820m and below there is no movement of water inside the tubing i.e. there is no leakage in the tubing and above that- velocity of water moving up increases as more water is entering the tubing through leakage points at depths where there is an abrupt increase in velocity.

Thus WFL measurements, validated the findings of spinner that at several places, water which is injected through the annulus of tubing and casing is entering the well bore through tubing leak points.

Subsequently, in February 2013 during workover job old tubings were replaced with new 13 Cr, 3 1/2" FOX tubings and only after that the problem of annulus pressure build up could be successfully rectified.

Well "C"

Well "C" a deviated producer having max angle of 54 degrees was producing with a high water cut even after isolating the lower zones by Mechanical Plug Back Tool(MPBT). The well was completed in 5" Liner in the interval X591-X601m.

The well was closed initially as it was producing gas only but reopened later. After reopening, the well started producing with high water cut of about 97% from the existing perforation (X616m-X622m). Based upon the open-hole logs (Resistivity, Density-Neutron), a potential gas zone was identified above the current perforations. In order to improve the productivity and reduce the water cut, it was decided to perforate the potential gas zone above and isolate the flow from existing perforation. Gas zone identified was perforated in the interval X591m-X601m and to provide isolation from the bottom, MPBT (Mechanical Plug Back Tool) set 2 m above the previous perforation (X614m) with cement being dumped over it. After additional perforation and MPBT (Mechanical Plug Back Tool) setting, surface rates increased and water cut still remained high (97%).

Production Logging was performed in this well in January 2013 to evaluate the integrity of the MPBT plug and to locate the source of water entry. As per merged

Temperature Logs, some activity was observed below the perforated interval at X601m and above MPBT at X614m. (**Fig-XII**) However, Spinner data does not reflect any flow inside the casing, thereby, suggesting that MPBT is hermetically sealed. Further, it also emerged that water was entering the well bore from the bottom part of the perforation at X601m.

As the zone perforated is a gas zone and based on temperature, USIT and SCMT log, a possible channel across the casing below the perforation (X591.0m–X601.0m) was expected; to validate the same Water Flow Log Survey was designed.

Recorded Water Flow Logs revealed that at a depth of X606.8m, water is moving up behind casing with a velocity of 321.44 ft./min and entering the well bore from bottom of the perforation at X601m.(**Fig-XIII**)

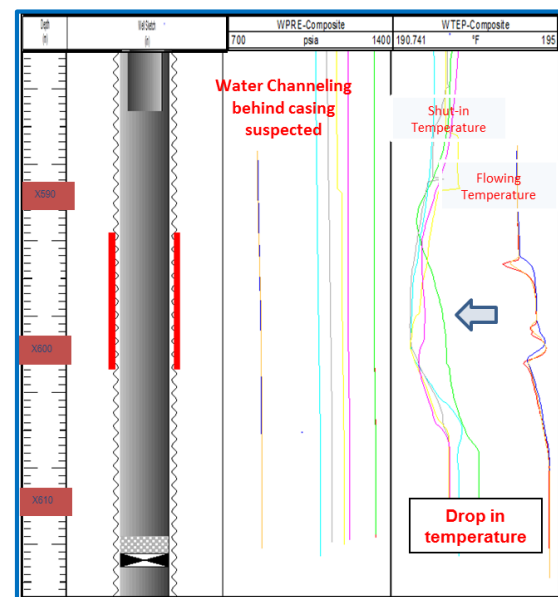


Fig.XII: Merged Temperature Logs

Subsequently, in a recent work over job, the well was side-tracked for exploitation of gas.

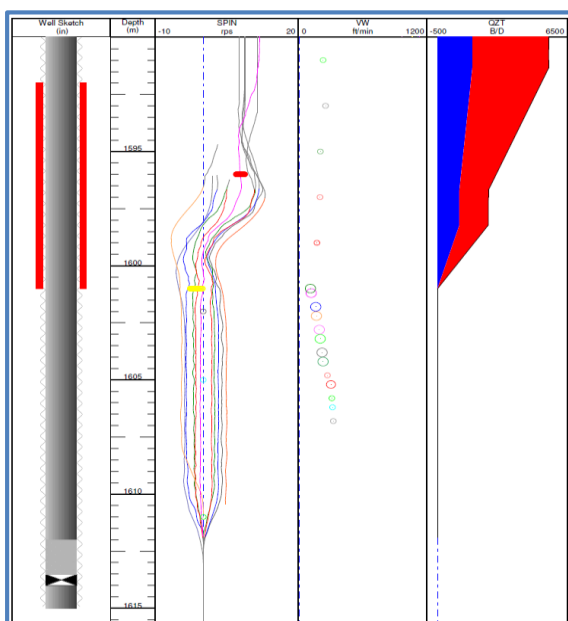


Fig.XIII: Water Flow Survey and Production Logging

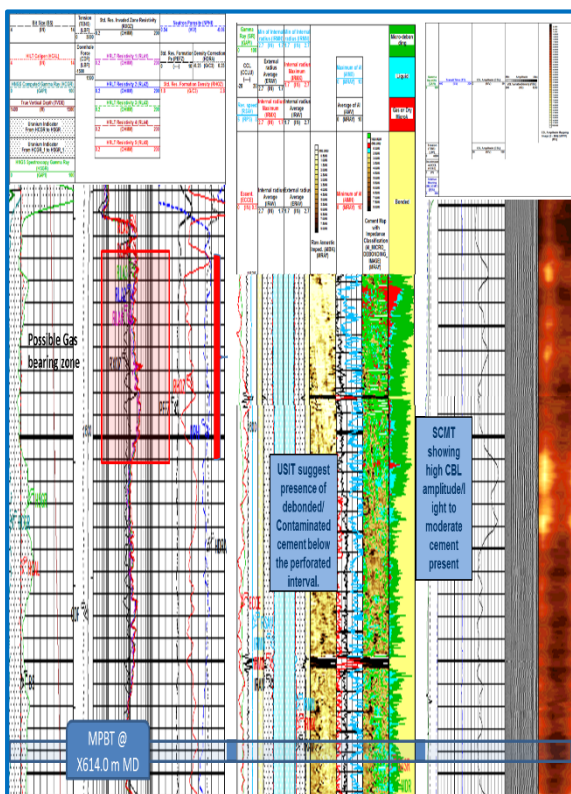


Fig.XIV: Open Hole and Cement Evaluation Logs

Conclusions

Three case studies of Western Offshore where Water Flow Logs were recorded were discussed in the present paper.

In well “A” an injector, Water Flow Survey established that both the Packers in 7” liner and 9-5/8” casing are leaking, besides, it also emerged that there exists damage in 9-5/8” casing at around X62m through which injection water is escaping outside.

In well “B” also an injector, Water Flow Log measurements corroborated the results of PLT survey and it was concluded that completion tubings were leaking at several intervals. Subsequently, in February 2013 during workover job old tubings were replaced with new 13 Cr, 3 1/2” FOX tubings and only after that the problem of annulus pressure build up could be successfully rectified.

In well “C” a producer, recording of Water Flow Logs revealed that high water cut is because of water which channelling up behind casing from below and finding its way inside the well bore through bottom of perforations at X601m. Subsequently, in May 2013, the well was side-tracked for exploitation of gas.

Thus, Water Flow Survey has emerged as an effective stand alone technique of detecting tubing leaks and identifying movement of water both inside and behind casings/tubings.

Ideally, Water Flow Measurements should be carried out in conjunction with conventional Production Logging Sensors to validate movement of water, inside and outside well bore.

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