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"Water Shut-off by Gel &Cement based on Production Logging: A case study"

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Abstract:

Gandhar, the largest onshore oil field of ONGC, falls under Broach sub-block of Cambay basin. The field discovered in 1983 has 12 different sands in Hazad member of Ankleshwar formation. Unlike Ankleshwar oil field, Gandhar field is mainly devoid of live aquifer support. As a result of the heavy initial production, the pressure of the reservoir started declining rapidly. So water and miscible gas injection schemes, implemented during the first phase of field development itself resulted in moderate to very good recovery factor of different sands. Heterogeneity being the norm rather than the exception posed a problem of preferential movement of injected water through high permeable layers. Production Logging jobs are carried out to understand production or injection behavior of the wells *in situ* and accordingly water shut-off or profile modification jobs are carried out. Injection water breakthrough becomes evident due to contrast in salinities of formation & injection waters.

This paper deals with the case study of water shut-off jobs executed after ascertaining the water contributing part of perforated interval in one well each of Gandhar & Jambusar fields. The PLT was carried out *sans rig;* and based on its result a work-over rig was deployed to carry out high volume gel job – Gel volume and configuration decided by IRS - to prevent water coning. The job was planned by first putting a hanging plug to avoid injecting gel in the entire perforations and then perforate 2m immediately below hydrocarbon contributing interval to squeeze high volume gel followed by cement. After a gel settling time period as suggested by IRS team, the upper part of the intervals was perforated. On activation, the wells produced oil and gas without any water cut.

Introduction

The largest on-land oilfield Gandhar in Jambusar-Broach block of South Cambay basin produces hydrocarbon from deltaic sands of the Hazad member. The field was discovered in 1983 and is producing oil & gas from different sand units defined as GS-1 to GS-12 from bottom to top. The reservoir hardly have any live aquifer support and thus has been on depletion drive. So IOR/EOR schemes were adopted & implemented in the form of water injection and sub-miscible gas injection nearly *ab initio*. This has resulted in a better recovery but simultaneously has added to woes in the form of injection water break-through from these layers even after some profile modification jobs. In such an environment reservoir monitoring by periodic PLT jobs particularly in wells under injection & taking corrective measures is of paramount importance.

Water front movement has been observed in the old wells with the help of Carbon-Oxygen log and Cased-hole resistivity. There have been few instances where zonal isolation by cementation & its evaluation, particularly high-pressure water bearing zone and depleted hydrocarbon bearing zone, has

posed new challenges for logging. Production logging techniques in these environments has been of immense help.

Production Logging has been carried out in more than 59 wells during 2013-2014. Examples included in this paper pertains to Identification of water channeling behind casing having best cement evaluated conventionally & by latest cement mapping techniques.

Well Gandhar # AAA

The well G # AAA was drilled as a S-profile development well for oil production from sand GS-12. Conventional Open-hole log suite comprising of DLL-GR-SP, ZDEN-CN-GR-CAL; and DSI-GR for 3D-3C was also recorded. Based on Log interpretation and other geological information, sands GS-1 and GS-2 were identified as hydrocarbon bearing and further recommended for testing.

Objective sand GS-12 is developed with two shale breaks in between at XX18.5-XX20m and XX23.5-XX23.8m. Upper layer of GS-12 sand (XX15-XX18.5m) was found to be shaly and has a resistivity of 2-3Ωm and GR 50-70 API. Computed effective porosity was found to be 8-10% only. The sand has 100% water saturation and was interpreted as water bearing.

The middle part (GS-12M) in the interval XX21-XX23.2m is characterized by a resistivity of 3.5-4Ωm and GR 30-45 API. Effective porosity and water saturation was found to be 22% and 65-70% respectively. This interval was interpreted as marginally hydrocarbon bearing.

The lower part of GS-12 sand (XX24-XX26m) is having a resistivity of 4-5Ω-m and GR 35-50 API. Effective porosity and water saturation were calculated as 20% and 62-70% respectively. This interval was interpreted as hydrocarbon bearing.

Later on, it was decided to test the objective sand GS-12M and perforated the interval XX21-XX23m @ 18 SPM conventionally. On initial testing, the well produced 52.8 m^3/d liquid with 98% water cut through 15mm bean. Drilling Rig was released for next location. Production logging *sans Rig* was planned to find out the source of water.

Production Logging

During production logging the well was flowing with a FTHP of 30 KSC on GLVs producing @ 59 m^3/d with 98% water cut with salinity of 17gpl. Conventional PL logs viz: Flow-meter, Temperature, Hydro, Density, Pressure, GR & CCL, were recorded in flowing and 3 passes subsequently in shut-in condition.

The PL log analysis reveals that though it appears as if the contribution is from open interval only but there is channeling from below. Upper 1 m of perforations are contributing hydrocarbon and bottom 1m is producing water via channeling from below. This is corroborated from different sensor responses at respective depths. There is no indication of any channeling / contribution by PLT from upper water bearing layer. As water contributing layer is close by and secondary cementation/channel repairing always remains subjective, a water shut-off job preferably by gel & cement squeeze was suggested.

The salinity of GS-12 water is nearly 25gpl but reported salinity of water being produced was 17gpl. This can only be explained by breakthrough of injection water from nearby wells.

Result

Based on the PL interpretation, work over job was planned in the well G#AAA. A high volume gel job was planned. Existing perforation were isolated by a hanging plug and perforation in the interval XX24-XX26 was done for gel & cement squeeze. Subsequently well was cleared up to XX23.5m and once again the interval was perforated 0.5m above the earlier zone. On activation with GLVs the well stabilized production @ 59.62m^3/d of oil.

Well Jambusar # BBB

The well JAM#BBB was drilled as a development well to extract hydrocarbon from the sand JS-1. It was drilled to a depth of XX74m as L-profile well with maximum deviation of 17.2^0 at 1328.6m and was terminated in Cambay shale. Open-hole logs viz. Resistivity (DLL-MLL-SP-GR), Neutron-Density (ZDEN-CN-CAL-GR), and FMI-GR to ascertain the formation dip were carried out. Based on well log interpretation, sand JS-1 was interpreted as hydrocarbon bearing while JS-2 & JS-3 were interpreted as water bearing.

The objective sand JS-1 consists of two clean and porous sand layers in the intervals XX33.5-XX35m and XX40-XX43.5m. The sand layer in the interval XX40-XX43.5m is having resistivity in the range 65.0-150.0Ω-m with GR of 35 API. The porosity and water saturation calculated were 22% and 15% respectively. The sand interval was interpreted as hydrocarbon bearing and recommended for testing.

The sand layer in the interval XX33.5-XX35m is showing resistivity 4.0Ω-m with GR around 45 API. The porosity and water saturation was calculated as 20% and 80% respectively. This layer was interpreted as water bearing. The other parts of this sand are shaly and impervious.

On testing the interval XX40.5-XX43.5m of JS-1 sand, it produced 73m^3/d oil and 21000m^3/d gas through 6mm bean. The well was completed in JS-1 sand.

After producing 38714 tonnes of oil and 11.02 MMm^3gas, the well started to show an increase in water cut. Rig-less Production Logging was planned to find the source of water.

Production Logging:

This well was producing 60m^3/d with 100% water of salinity 2.05gpl at the time of production logging. It was flowing on GLVs with a FTHP of 18KSC. Gamma-TCL-Temperature-Pressure-Density-CWH-Flow-meter logs were recorded in both dynamic and static conditions.

The PL logs suggest the contribution from zone only without any indication of channeling from above or below. The first fluid entry is observed from the bottom most perfs. Hydrocarbon entry as suggested by density log is at XX42.5m. Abrupt fall in temperature against the top-most perfs is suggestive of gas entry. So water contribution is from the bottom 1m of open interval. (Fig. 2)

As is obvious it appears to be a rise in OWC which has been observed in other wells deeper than this. It was therefore recommended to carryout water shut-off job in bottom part and to complete the well in upper part of the present sand layer itself.

Work Over Job

Based on work-over plan the well was cleared down to XX60m by drilling the cement hanging-plug placed to protect the reservoir. Subsequently 20 m3 gel followed by 500 ltrs cement squeeze job was carried out after perforating the bottom part of the layer in the interval XX42.5-XX43.5. Well was subsequently perforated in the upper part in the interval XX39-XX42m only and completed with GLVs. On activation it flowed oil @ 31.75 m3/day with negligible water.

Conclusion

The production logging tool remains the best in situ diagnostic device. Periodic PLT in producing or injection wells usually forewarn about the health of the reservoir in times to come and an individual well also. Down-hole completions quite often yield to differential pressures resulting in unwanted channeling. Remedial measures can be best resorted to only after having *in situ* knowledge. The above case studies are good example of tackling production problems in reservoirs under water injection and other having a natural aquifer support.

Acknowledgements

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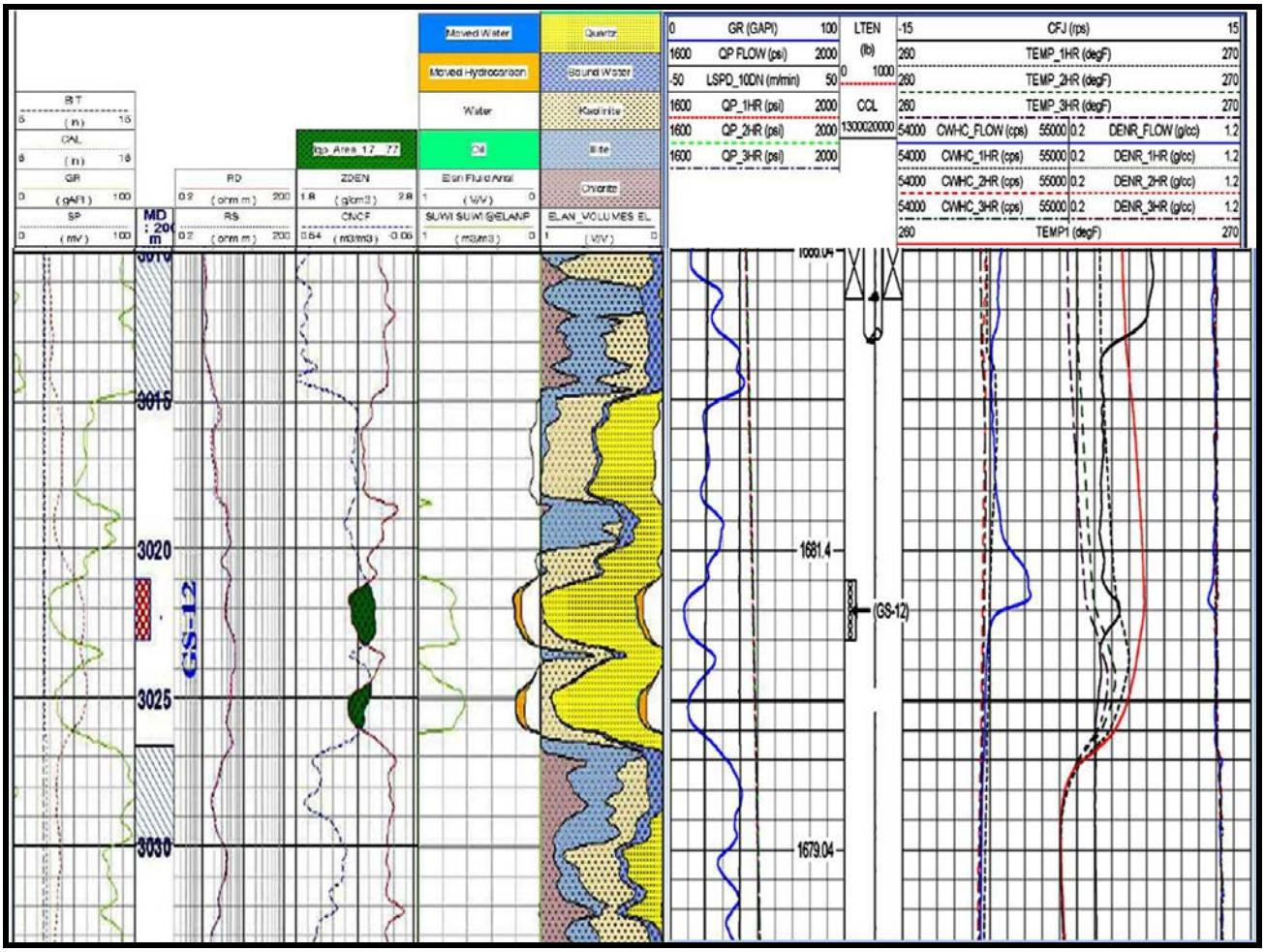
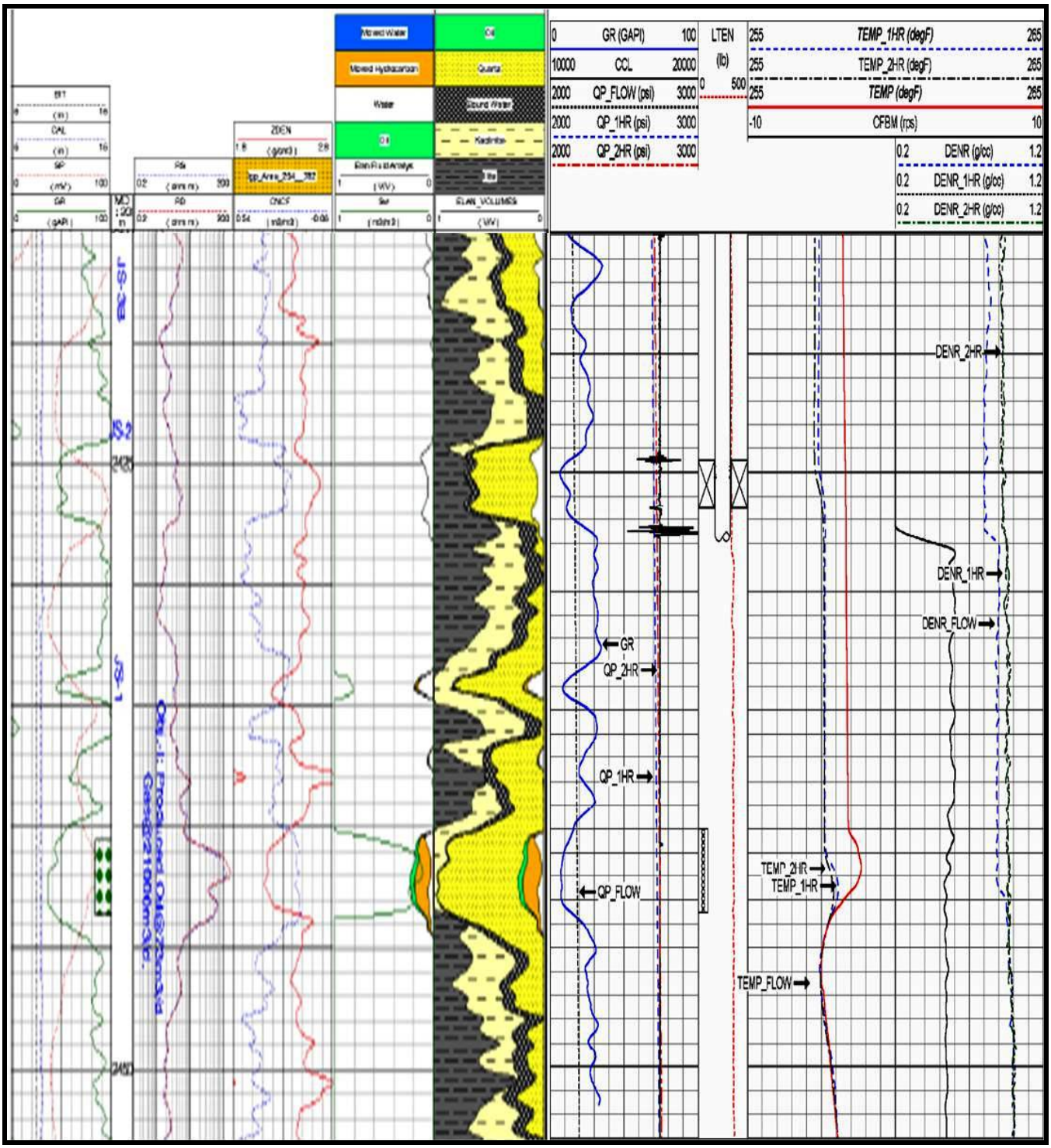
References

1. FERs of corresponding wells.

2. Production logging reports



(Fig. 1) Production Logging response in well Gandhar #AAA



(Fig. 2) Production Logging response in well Jambusar #BBB