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IMPLEMENTATION OF USR RE-ENTRY TECHNOLOGY TO REVIVE POOR PRODUCERS IN GELEKI FIELD OF ASSAM ASSET

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ABSTRACT

The objective of the paper is to create awareness of state-of-art ultra short-radius drain hole drilling technology applicable in mature and tight reservoirs, logistically difficult terrains and thin oil pays to enhance oil production from existing sick wells through cost effective intervention of USR horizontal well completions at a fractional cost of drilling a new well. USRDH drilling campaign has cutting edge over simple work over jobs to improve reservoir drainage and productivity from existing low or non producing wells.

In 2007, ONGC Assam Asset successfully completed first USR horizontal re-entry well in Geleki field. The cost of re-drilling one USRDH well there worked out to only 0.5 to 0.8 times as expensive as vertical well, while a new onshore horizontal well from the surface would have cost 2 to 2.5 times the vertical well.

The “learning curve" and impressive results of USR wells are likely to form a major part of revival strategy to maximize reservoir exposure and recovering left behind oil in shut-in wells. This paper seeks to bring out the concept, various aspects, unique challenges and operational practices of USRDH technology field-tested in Assam Asset of ONGC for faster exploitation and improved recovery.

Introduction:

Reviving production from declining fields with cost-effective interventions has become a major focus for Assam Asset. In some cases re-entering the existing wells for drilling a horizontal lateral is a better option, rather than a simple work-over. USRDH drilling campaign has cutting edge over simple work over jobs. Ultra short radius (USR) re-entry and completion system is one quick and cost effective solution for widening the application of horizontal drilling to existing wells. USR technology allows value addition to the assets by variety of applications in low producing wells, tightly spaced fields, wells with water coning, channel sands with surrounding shale and exploitation of attic oil. The objective of the paper is to create awareness of Ultra Short-Radius Drain Hole (USRDH) drilling technology applied in mature and tight reservoirs, logistically difficult terrains to improve reservoir drainage from existing low producing well of Geleki Field in Assam through horizontal completions at a fractional cost of drilling a new well.

USR Concept and Technology Application:

Horizontal wells are typically grouped in four categories: Long radius, Medium radius, Short radius and the Ultra short radius - according to radius of curvature described by the well bore as it passes from the vertical to the horizontal. The state-of-the-art Ultra short radius (USR) technology has the ability to re-enter a vertical well and drill a horizontal drain-hole with shortest possible radius of curvature (8-12m) where the TVD consumed by curve is less than 12m and restricted to the pay zone by keeping high build up rate (close to 250° per 30m) and lateral departure of about

150 m length. Multiple laterals can be drilled in opposite directions or same direction, with kick-off points (KOP) spaced minimum of 2.5 m apart. The kickoff, curve and lateral sections are kept entirely within pay zone to avoid problems with overlying formations, shale beds and minimizing the risk of stuck pipe. Wells may be completed in open hole if bore-hole is stable or with slotted pipes for sand control and hole integrity.

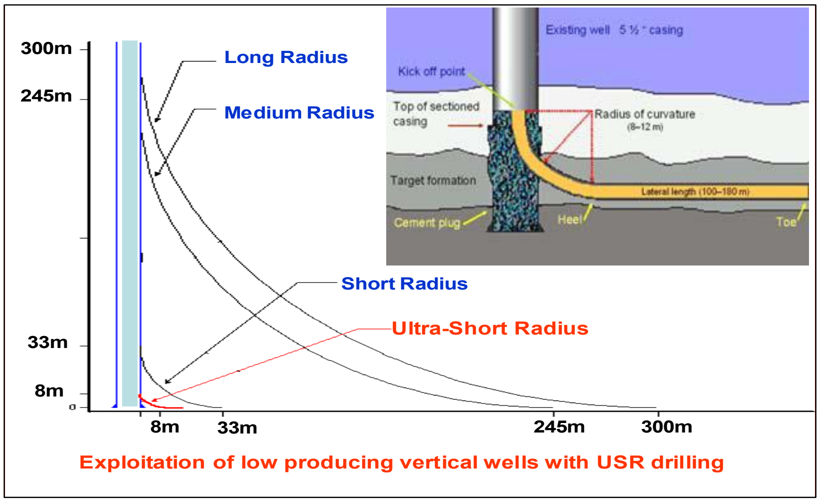


Fig-1 USR Concept and schematic of horizontal drain hole from existing well

USR horizontal drilling is the preferred option in heterogeneous / low permeability / thin-layered / semi-depleted / naturally fractured reservoirs or when coning of water / gas expected to interfere with full recovery. Using USR horizontal drain holes, oil can be produced at low draw-down pressures keeping away water coning as long as possible and without reducing production rates.

The important aspects in USR technology are difficult directional control in the horizontal section, limited drill pipe rotation in the open hole, limited casing and bit size, the tight well bore curve, the weight on bit, bending of pipe in curve drilling, high torque, short lateral length due to the inability to overcome friction and put weight on bit and target formation suitability for an open hole or slotted liner completion. Measurement While Drilling (MWD) or Logging While Drilling (LWD) package and open hole-logging suites are not possible due to ultra short radius turns, bending concerns and non-availability of small / slim measurement tools.

USR Drilling:

The USR technology uses a purely mechanical Rotary Steerable System (RSS) operable from a work-over rig having a top drive power swivel and capable of drilling different hole sizes with any drilling fluid. An electronic tri-axial survey tool transmits down-hole survey data such as inclination, azimuth, magnetic field, gravity tool face, magnetic tool face and temperature from near the bit for surface read-out. The challenge of accurate directional control is met by stabilizing the bit to continually point along a tangent to curved path. Lateral drilling is purely a rotary process, using a point and shoot technology (i.e. the bit goes at pointed direction with less than 3° azimuth change).

Well Candidature:

Well selection and target interval identification for USR application is critically dependent on analysis of relevant well data, sub-surface data, well log evaluations, reservoir targets within practical reach, geological uncertainties, confidence in the reservoir simulation, current production profile, recovery efficiency, well bore stability, well-path trajectory constraints, collision risks, chances of safe drilling to the target, logistic considerations and re-entry cost.

Well planning process begins with the target interval selection i.e. direction of drain hole to be drilled avoiding problematic formations such as reactive shale, washouts, existing gas or water layers near the interested zone. The kickoff point to initiate the curve and the radius of curvature are chosen on the basis of the target interval thickness, landing point of the curve in the pay zone, lateral length, formation properties above the target zone, location of casing collars / centralizers / perforations, type of flexible pipe in use, casing and cement integrity, the number of laterals and completion requirements. Laterals may be planned as true horizontal or to traverse the target zone with toe up / toe down hole profile.

Suitability for TS-3A pays sand of Geleki Field:

A review of selected well performance and reservoir data of Geleki oil field showed that USR horizontal drain holes if completed in the upper part of the TS-3 reservoir, would produce more oil than a vertical wells in the same location and also take care of the unique problems in producing TS-3A sands that deter its optimum exploitation through conventional drilling due to low recovery factor (17- 25% of OOIP) attributed to lateral heterogeneity, existence of bottom aquifer, poor permeability, poor well influx and thin oil column. Geleki field TS-3A sand has 8-15m pay thickness from pay top to landing point. The oil column is either inherently less or reduced because of rising oil water contact (OWC). Short or Medium radius drain hole techniques require substantial true vertical depth (TVD) or long radius of curvature to make the well horizontal and are not feasible as the casing window needs to be cut in the overlying shale and / or water bearing sand for landing the drain-hole in thin oil pay. With such constraints, USRDH seems to be an apt technology for Geleki field, TS-3A pay sand to get advantage of larger pay contact area, higher productivity and extended economic life of matured field.

Field application and case study:

USR Geleki well Plan: A 12m radius of curve was planned in N 240º direction with landing depth of 4 ½" curve at 2437 m TVD. The 150 m long 3 ⅞" lateral section was designed to traverse up to 2435m TVD through the targeted Tipam sand stone reservoir (TS-3A) and well completion on GLV's by running 2 ⅜" pre-slotted pipes.

Well bore preparation: The well bore preparation phase which includes the section milling, under-reaming procedures, cement kickoff plug and dressing is critical to the USRDH well success. Existing perforations (2426-41m) were squeezed off with 300 litre slurry at 2500 psi. After clearing cement to 2450m, tested casing hermeticity at 150 kg/cm^2 and recorded GR/CCL/VDL logs. 5 ½" Casing window of 8m length (2423-2431m) was section milled. A flat junk mill & four string magnet assemblies worked through window portion before reaming with 8½" under reamer. A hi-vis pill was pumped and hole was circulated clean of metal cuttings. USIT log was recorded to confirm window depth and that the milled section being free of all metal shavings. If for any reason, the section interval is contaminated with pieces of metal, there is very high likelihood of damage to the drilling assembly. Section milling and under reaming operations were affected due to frequent problems of continuous flow of semi-solid crude oil, rusted scale-junk from the Drill-Pipe, metallic junk inside the 5½ '' casing annulus. A 100m kick of cement plug #1 was placed from 2439-2339m and hard cement dressed upto 2424m with 4 ½" PDC bit without nozzles. Thereafter Bentonite gel mud (1.09SG) was circulated for two cycles and changed over to KCL-Polymer mud prior to curve drilling.

Drilling 4 ½" USR Curve with the Rotary Steerable System (RSS):

a). Curve #1 (Drilled depth : 2424 to2442.2m) : After orienting tool face at 237.17º azimuth with Gyro tool, drilled 4 ½" curve from 2424-2426.70m, it was attempted to circulate but nozzle were found plugged. String was reciprocated but survey tool could not be stung in. In the second attempt, curve drilling assembly (CDA) was successfully lowered, with tool oriented to high side and drilled 4 ½" curve from 2426.70-2442.20m (angle 87.2º, azimuth N 241.53º, TVD 2435.23m). While drilling 3 ⅞" lateral rat hole with PDC bit & mud motor from 2442.2-2445.60m, pressure loss was observed due to snapping of the titanium pipe and a fish of 20.76m length consisting of 2 numbers of Titanium DP, wobble sub, string stab, wobble sub, near bit stabilizer & 3 ⅞" PDC bit was left in the hole. Fish could not be recovered even after 14 repeated attempts.

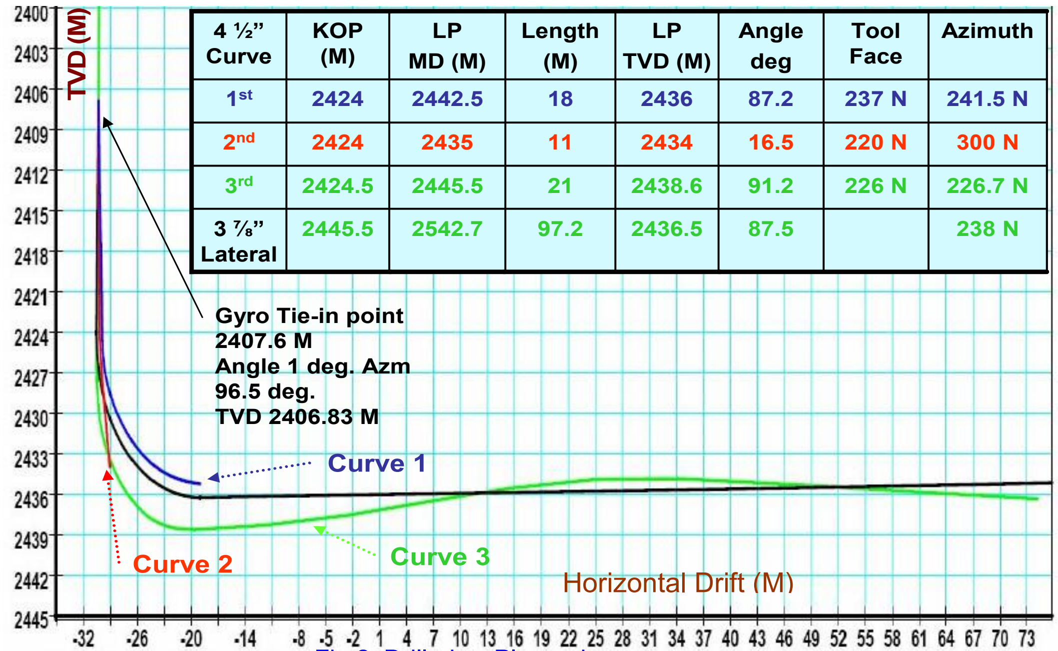
b). <u>Curve #2 to bypass the fish (Drilled depth: 2424 to 2435m)</u> : A cement plug #2 from 2431-2308m was placed and dressed off the to 2424m. The curve #2 drilling was started from 2424-2429.20m. CDA tool face could not be aligned to desired direction (angle 16.9º, azimuth N 301.85º, TVD 2428.36m). The hole was reamed from 2424-2429.20m with 4 ½" clean out assembly twice and drilled further from 2429.20 to 2435m at high to intermittent torque. In two repeated runs, tandem 3 ½" string magnet assembly was worked through 2422-2435m section with 1150 gm of metal recovery. Further four tandem magnet runs on wire line unit recovered 800 grams of metal. Second curve had to be discontinued due to metal junk generated during the drilling and large quantities of the metal cuttings in hole.

*c). <u>Curve # 3 (Drilled depth: 2424.50to 2445.50 m)</u> :*Undaunted with two failures, with the ambition to attempt third curve successfully, sidetracking cement plug #3 was set from 2432.70-2321m and hard cement dressed off to 2424.50m. Drilling on curve #3 started with KOP at 2424.50m, the first 2m of the curve was drilled to 2426.50m with mud motor bend set at 4º. At 2445.50m (MD) depth, the curve attained N 226.7º azimuth, 91.2º inclination and 2438.50m (TVD). The detail of curve drilling is tabulated below:

Assy.	Bit Sub length	4½" curve (m)	TVD (m)	Angle º	Azimuth	Remarks
CDA#1	Mud Motor	2424.5-26.5	2425.40	4.5	N 226º	Gyro tie up point 2407.56m
CDA#2	7 ½"	2426.5-32.5	2431.50	29.9	N 196º	No angle built, High torque
CDA#3	6 ¾"	2432.5-39	2436.50	50.7	N 224 º	Unable to get BUR & LP
CDA#4	6 ¼"	2439-45.5	2438.53	91.2	N 226.7º	Extended LP TVD to 2440m

Drilling 3 ⅞" Lateral with articulated mud motor drilling system:

<u>3 ⅞" Lateral Section (Drilled depth 2445.50 to 2542.70m)</u>: Using rotary lateral assembly, 3 ⅞" rat hole for mud motor was drilled from 2445.50-2449.50m. Further, 3 ⅞" lateral section from 2449.50-2486m was drilled with steerable motor lateral drilling assembly (LDA) #1. The 3 ⅞" bit got worn out & was changed, further drilling down to 2521.50 with LDA #2. ROP gradually dropped down and then further penetration could not be achieved. PDC bit replaced roller cone and in 120 minutes drilled from 2521.50-2522m with LDA#3.



4 ½" Curve	KOP (M)	LP MD (M)	Length (M)	LP TVD (M)	Angle deg	Tool Face	Azimuth
1st	2424	2442.5	18	2436	87.2	237 N	241.5 N
2nd	2424	2435	11	2434	16.5	220 N	300 N
3rd	2424.5	2445.5	21	2438.6	91.2	226 N	226.7 N
3 ⅞" Lateral	2445.5	2542.7	97.2	2436.5	87.5		238 N

Fig.2: Drilled vs Planned curves

Again a decrease in ROP was observed. The formation being sticky clay stone, the PDC bit was getting balled up. With 3 ⅞" mono cone bit LDA #4, even 10 cm drilling could not be achieved in an hour. With a new Smith 3 ⅞" OFM bit and mud motor, reamed up to 2522.70 m, continued lateral drilling till 2542.70 m with intermittent wire line survey. Again a drop in ROP was observed. Final survey for angle (87.50 °) and azimuth (N 238°) was taken prior to discontinue drilling.

Well was kicked off at the top of targeted TS-3A sand. The entire drilled curve as well as lateral was kept within the Tipam pay sand without passing through shale or going close to underlying water. Excellent hydrocarbon shows were encountered even while drilling the curved and horizontal sections.

Drilling Fluid Policy:

The casing milling operations were carried out with high viscosity bentonite gel supplemented with PGS. Well was circulated with high-viscous pills to remove all the cuttings and junk. After milling, USR operations were carried with clay-free non-damaging KCl-Polymer mud system to minimize formation damage and maintain borehole stability and cake quality. Mud was treated continuously with (1) PAC-R, PGS to maintain fluid loss and viscosity, since water loss remained high due to heavy rains, (2) Calcium carbonate to maintain mud weight, (3) Caustic soda to maintain pH value around 9.0, (4) Biocide to avoid degradation of polymers, (5) EP Lube to provide enough lubricity in the down-hole to avoid pipe sticking.

Casing Scraping and Well bore clean up:

The 5 ½" casing scrapper was run with 3 ⅜" jet bull nose and 12 joints of Titanium DP to 2542.70m well TD, circulating intermittently polymer mud (1.07/ 50-52 sec). The drain hole was circulated clean using Power Wash chemical. Pumped 4 m^3 high viscous pill for cycle up and *Power Wash solution* (50% Power Wash plus 50% brine) for cleaning the mud cake formed in the lateral section. The lateral section was allowed to be soaked in the solution for 2 hours, by pulling up string to casing shoe. The string was lowered back to bottom and displaced fluid inside the hole with brine (1.08 SG) thereby circulating out Power Wash. A good amount of mud filter cake was observed with the pill on bottoms up. The well was displaced from Non-Damaging Drilling-Fluid (NDDF) to NaCl brine (1.08 SG, pH 9.5).

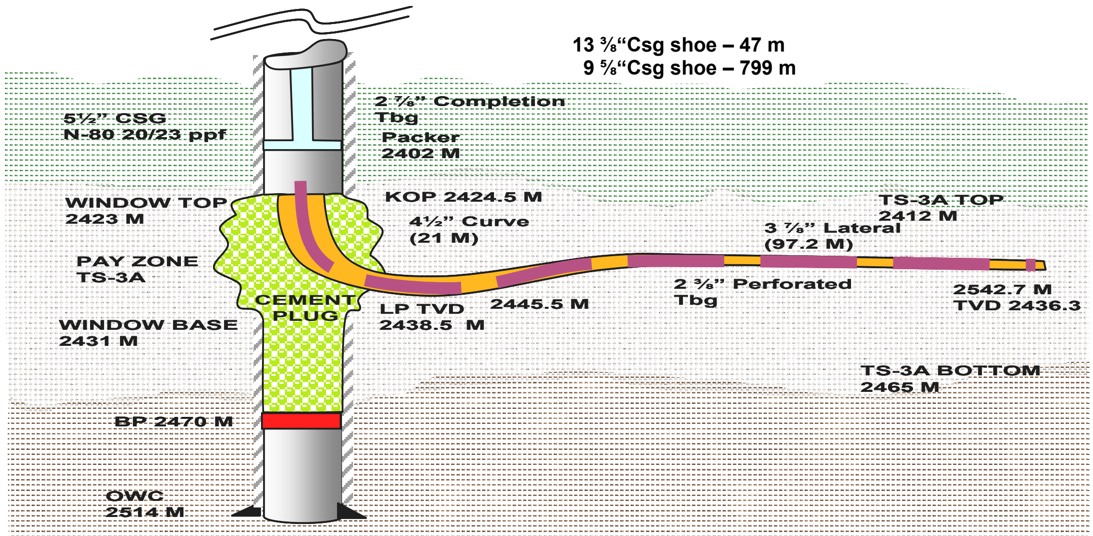


Fig. 3: USR Completed Well in Geleki

Well Completion:

The curve and the lateral was protected by running in 13 joints of 2 ⅜" EUE pre-slotted pipes on LH crossover with 2 ⅞" EUE tubing to bottom without observing any obstruction and released the pre-slotted pipes (123.5 m) in the lateral portion with 15 RH turns. 2 ⅞", EUE, L-80, 6.5ppf completion tubing string was run in with 2 pup joints and POP (pump out plug) as tail pipe on 5 ½" hydraulic packer. Total seven GLV's (gas lift valves) were installed. Set 5 ½" hydraulic set retrievable permanent packer at 2401.45m with 3000 psi pressure actuation. Continued pressure build up to 4200 psi in attempt to shear ball seat, but failed. The ball was left in place so that POP cage with setting ball could act as standing valve. *Well was activated with compressor and flowed with gas lift to GGS on 10th Aug'07. Sweet success was tasted when the almost non flowing well started producing oil at the rate of about 20-24 M^3 per day under gas injection.*

Benefits analysis:

USRDH technology provides a simple cost effective solution to derive maximum production benefits from ageing fields with a brand new lengthy horizontal drain hole. Re-entry USR horizontal sidetracking from the existing well bore is usually less expensive than drilling a new well to kickoff point. The cost of drilling one USRDH well in Assam Asset is around INR 6.00-7.00 Crores which is only 0.5 to 0.8 times as expensive as vertical well; while a new onshore horizontal well from the surface costs 2 to 2.5 times the vertical well. Re-entry has the advantage that borehole trajectory through the production zone is near the original well bore where much is known about the reservoir from cores, logs, test measurements and production history. This would help in addressing problems of sick wells and rejuvenate them with minimum interventions.

Future application scenario:

The impressive results and success of USRDH well will form a major part of revival strategy to produce oil that have been by-passed in vertical wells of Assam Asset. ONGC has many mature, declining, brown fields; this technology provides a breakthrough for rejuvenation and enhancement of production from existing sick wells. It finds immense application to avoid liquidation of such wells and rather convert them into a 'NEW" well with manifold production opportunities. Concerted and sincere MDT approach to induct USR technology has demonstrated the success in the field implementation.

References:

(1) Oman Tests Short Radius Technology - by Karl Lang, Hart's E&P Technology Sections - Oct 2002
(2) Re-entry Drilling Gives New Life to Aging Fields – Schlumberger Oilfield Review, Autumn 1996
(3) Slim Hole Rotary Steerable Short Radius Horizontal Drilling System - by J. David Parade, Torch International LLC, SPE Dubai, UAE March-2003
(4) Torch International - The Short Radius Company, Muscat Oman - Brochure