Novel Perforating Charges Maximizes Oil Production verifying the Modeled Perforation Performance

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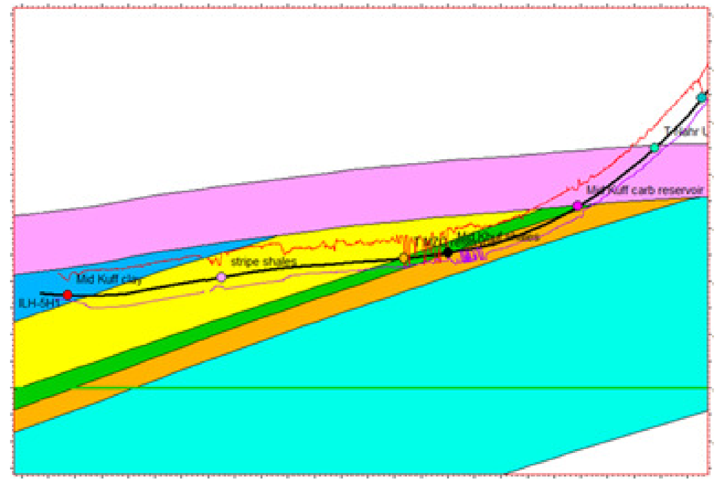
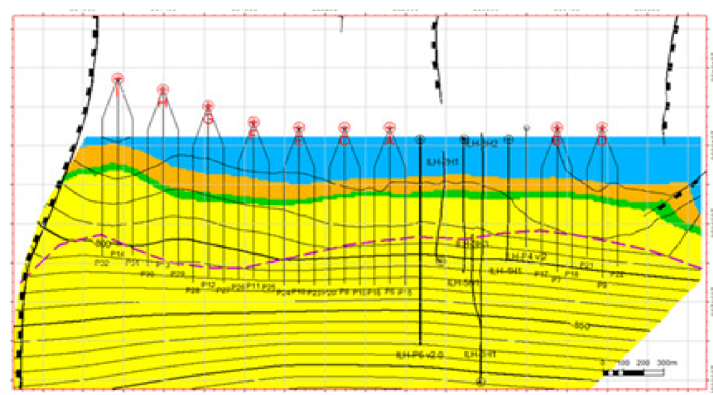
Outline :

- Background
- Challenges of Horizontal Well Perforating
- Workflow & Method .
- Gun Comparison .
- Results and Discussions
- Conclusion

BACKGROUND

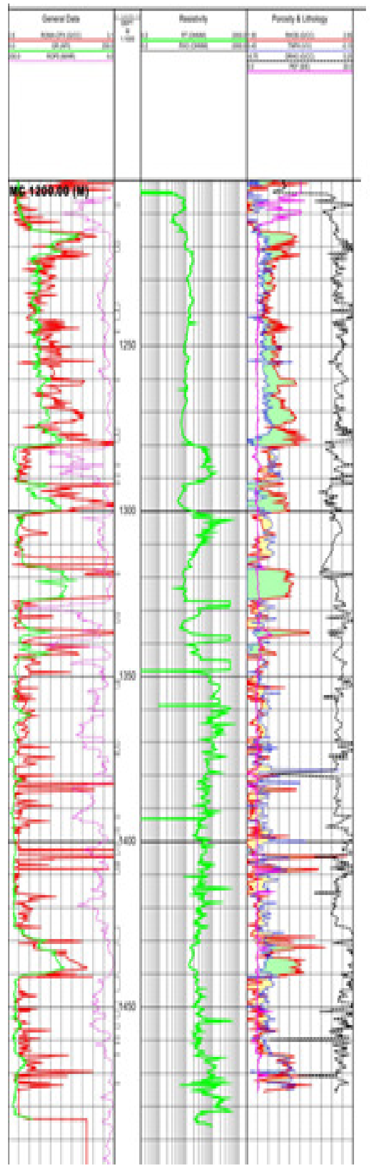
- Anon-active; unconnected promising field within a mature cluster was re-discovered
- A right decision drilling & completion technique to be reviewed
- Heavy oil is the main factor to be considered





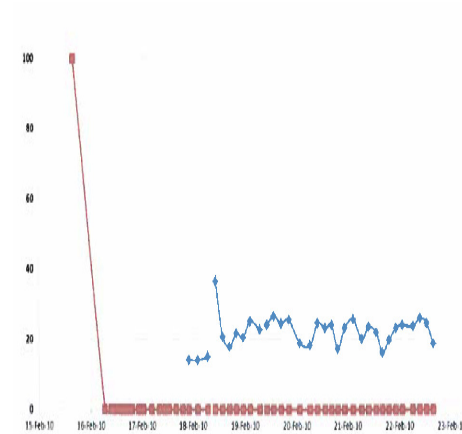
CHALLENGES

- Available Well location and target made the decision to complete the well – highly deviated
- Time and outcome as the constraint
- Perforating long intervals on horizontal wells requires a dedicated understanding of the reservoir properties and diligent perforation design.
- Medco decided to perforate the long interval (133 m) of a highly deviated well
- minimizing the number of runs required throughout three reservoir intervals.



perforted 4.5" cemented liner @
1280-1291 m MD (11m) Mesozoic Clastic fm
1300-1316 m MD (16 m) Mesozoic Clastic fm
1326-1432 m MD (106 m) Mesozoic Clastic fm

Meas Depth	Incl.	Azim
Meter		
1,339.00	**77.58**	**181.61**
1357.00	80.03	184.59
1376.00	82.08	185.00
1396.00	82.40	185.63
1415.00	80.28	186.32
1434.00	82.50	184.66
1453.00	81.83	184.34
1471.00	84.69	180.82
1484.00	85.35	178.52
1500.00	85.50	178.00



WORKFLOW & METHOD

- An underbalanced perforating strategy was embraced to better clean the perforation tunnels
- Perforating design was performed by perforation analysis software to compare the various gun systems and the resulting well productivities.
- Perforations were conveyed on tubing and the gun shock models were created

Perforating System(s)

Perf #	Loaded Length (m)	Phasing Angle (deg)	Shot Density /Open Perfs (spf/%)	Eff Shot Density (spf)	PURE Density (spf)	Crush Zone kc/k	Crush Zone (in)	Form Pen Avg (in)	Form Dia Avg (in)	EH Dia Avg (in)
1	255.0	60	6.00/100	6.00	0.00	0.09	0.50	16.63 *	1.09	0.36
2	255.0	60	6.00/100	6.00	0.00	0.05	0.50	21.97 *	1.16	0.38
3	255.0	60	6.00/100	6.00	0.00	0.06	0.50	27.44 *	1.13	0.37

* Rock-based Model: Based on lab experiments in rocks with UCS up to 18k psi under downhole conditions

Perf #	Eff Skin	Darcy Skin	Perf Skin	Crush Zone Skin	Deviation Skin	Partially Open Skin	Non-Darcy Coef (1/STB/day)	Non-Darcy Skin	PR	PI * (STB/day) (/psi)	Flow * Rate (STB/day)
1	-0.14	-0.14	-0.14	0.77	0.00	0.00	2.547e-9	2.675e-6	1.02	0.77	1159.2
2	-0.14	-0.14	-0.14	1.17	0.00	0.00	2.407e-9	2.528e-6	1.02	0.77	1159.2
3	-1.15	-1.15	-1.15	0.68	0.00	0.00	2.059e-9	2.523e-6	1.19	0.90	1352.9
OH	0.00	0.00	0.00	0.00	0.00	0.00	0	5.707e-7	1.00	0.76	1136.6
OHdmg	5.45	5.45	0.00	0.00	0.00	0.00	2.992e-9	1.755e-6	0.57	0.43	647.4

1.
2.
3.

* At the stable bottom hole flowing pressure Pwf=200 psi

Completion

Borehole Diameter:	5.5	in	Wellbore Fluid:	Brine	
Form Top (TVD):	1170.0	m	Fluid Density:	8.8	ppg
Form Bottom (TVD):	1425.0	m			

Tubular(s)

Casing #	Outer Diameter (in)	Weight (lbm/ft)	Grade	Inner Diameter (in)	Tubing Position	Stand-off	Annulus Material	Annulus Density (ppg)	Csg Str Remain (%)
1	4.5	11.60	L80	4	Centralized		Cement	8.6	97/97/97

Formation

Rock Type:	Sandstone		Rock Strength (UCS):	1500	psi
Porosity:	28.0	%	Vertical Stress:	4257	psi
Bulk Density:	2.17	g/cm3	Pore Pressure:	1700	psi
Formation Fluid:	Oil		Wellbore Damage:	8	in

Perforating System(s)

Perf #	Phasing Angle (deg)	Shot Density (spf)	PURE Density (spf)	Gun Position	Stand Off (in)	Total Pen Average (in)	Form Pen Average (in)	Form Dia Average (in)	EH Dia Average (in)	AOF (in2/ft)
1	60	6.00	0.00	Eccentered	0	17.38 *	16.63 *	1.09	0.36	0.61563
2	60	6.00	0.00	Eccentered	0	22.72 *	21.97 *	1.16	0.38	0.69341
3	60	6.00	0.00	Eccentered	0	28.19 *	27.44 *	1.13	0.37	0.65958

* Rock-based Model: Based on lab experiments in rocks with UCS up to 18k psi under downhole conditions

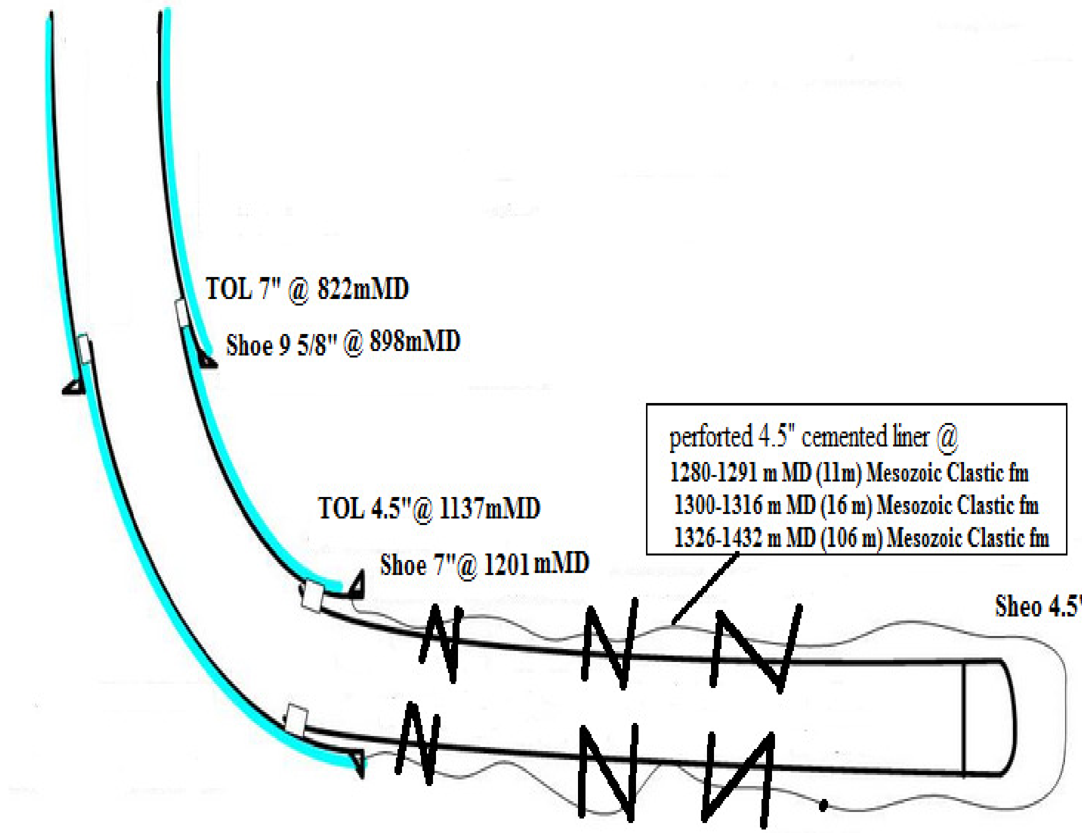
Gun System(s)

#	Name	Chg Wt (g)	Gun OD (in)	API Pen (in)	API EH (in)	Comment
1		15.0	2.802	25.30	0.38	19B 1st Ed
2		16.0	2.802	36.00	0.34	19B 1st Ed
3		16.9	2.802	30.70	0.38	19B 1st Ed

RESULTS :

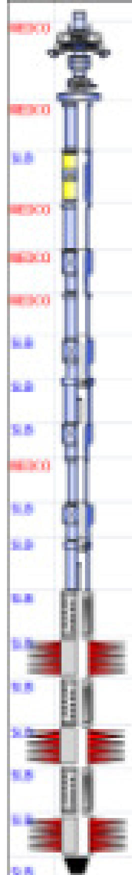
- The perforation operation was successfully performed without any operational and HSE issues.
- The actual production was in line with the expectations as predicted by the perforation analysis software.
- Production from the well was actually better than the neighboring wells in the same region.

No	Status	Start	End	Gross	Net Oil	Net Water	BSW
				m3	m3	m3	%
1	valid test	24/Jul/2013 00:00:00		27.47	25.10	2.40	8.60
2	valid test	20/Jul/2013 00:00:00		27.50	25.10	2.40	8.60



DISCUSSION

- The incremental cost on the perforation gun system has imperatively paid off by the gained production of oil.
- The rock based perforation penetration and a productivity model is an important input



2.88" TCP Guns 6 SPF will set inside 4.5" Liner

Pos.	Description	O.D.(")	I.D.(")	Box	Pin	Length (M)	Top Depth	Bottom Depth
MEDCO	Pump in Tee					1.25		-1.00
MEDCO	3 1/2" EUE Tubing To Surface	3.50	2.2	3 1/2" EUE	3 1/2" EUE	832	-1.00	830.55
S.B	RA Marker Sub	4.75	2.25	3 1/2" EUE	3 1/2" EUE	0.96	830.55	831.51
MEDCO	29 x Joints of 3 1/2" EUE Tubing	3.50	2.2	3 1/2" EUE	3 1/2" EUE	249.60	831.51	1081.11
MEDCO	Cross Over	3.08	2.2	3 1/2" EUE	2 7/8" EUE	0.30	1081.11	1081.41
MEDCO	18 x Joints of 2 7/8" EUE Tubing	3.50	2.2	2 7/8" EUE	2 7/8" EUE	172.80	1081.41	1254.21
S.B	Cross Over	3.08	2.2	2 7/8" EUE	2 3/8" EUE	0.12	1254.21	1254.33
S.B	LSDS (Long Slot Debris Sub)	3.50	2.2	2 7/8" EUE	2 7/8" EUE	0.55	1254.33	1254.88
S.B	Cross Over	3.08	2.2	2 3/8" EUE	2 7/8" EUE	0.12	1254.88	1254.98
MEDCO	2 x Joints of 2 7/8" EUE tubing	3.08	2.44	2 7/8" EUE	2 7/8" EUE	19.20	1254.98	1274.18
S.B	Cross Over	3.08	2.2	2 7/8" EUE	2 3/8" EUE	0.12	1274.18	1274.30
S.B	HDF (Hydraulic Firing Head)	3.08	1.2	2 3/8" EUE	3 3/8 API	3.00	1274.30	1277.30
S.B	2.88" Safety Spacer	2.88	****	3 5/8 API	3 3/8 API	2.70	1277.30	1280.00
S.B	2.88" 6 spf, PJ Nova 2906 HMX, TCP Guns	2.88	****	3 5/8 API	3 3/8 API	11.00	1280.00	1291.00
S.B	2.88" Blank Spacer	2.88	****	3 5/8 API	3 3/8 API	9.00	1291.00	1300.00
S.B	2.88" 6 spf, PJ Nova 2906 HMX, TCP Guns	2.88	****	3 5/8 API	3 3/8 API	16.00	1300.00	1316.00
S.B	2.88" Blank Spacer	2.88	****	3 5/8 API	3 3/8 API	10.00	1316.00	1326.00
S.B	2.88" 6 spf, PJ Nova 2906 HMX, TCP Guns	2.88	****	3 5/8 API	3 3/8 API	106.00	1326.00	1432.00
S.B	Bottom Nose	2.88	****	3 5/8 API	****	0.17	1432.00	1432.17

All logs should be referenced to the Original Drill-Floor Elevation (ODE) of the Rig

Top Shot to RA Marker: [illegible] meters

RA Marker Depth: [illegible] meters

[illegible] Drilling Representative

CONCLUSION

- The lessons learned from the operational stand point as well as the well to reservoir communication efficiencies as predicted and actually occurred.
- The choice on the novel perforation charge selection proved to be a fulfilling the needs
- The predicted production rates were matched by actual oil production proving the certainty of the input parameters for productivity modeling such as
  - reservoir permeability,
  - porosity
  - the fluid characteristics

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