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INTEGRATED APPROACH TO OPTIMIZE PERFORATION OPERATION IN HIGH PRESSURE GAS WELLS

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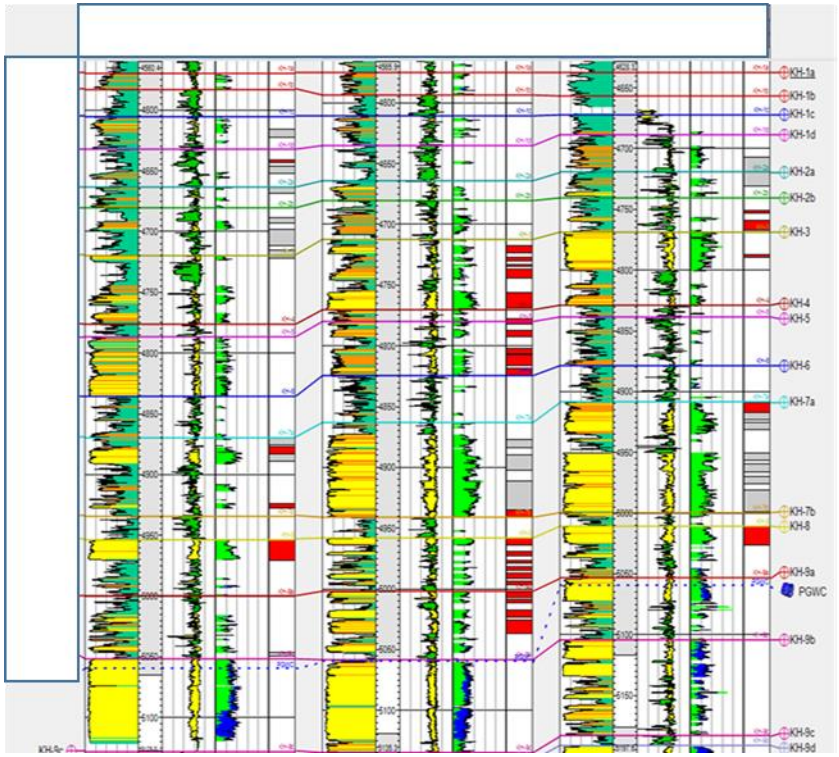
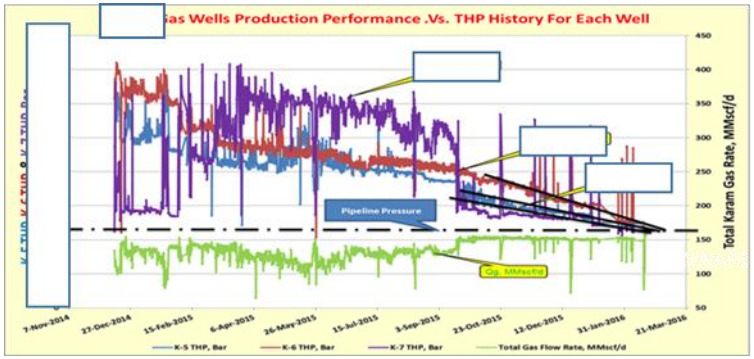
AGENDA

- Case Background
- Objectives & Challenges
- Details of the Integrated Approach
- Simulation Results
- Results & Summary

FIELD BACKGROUND

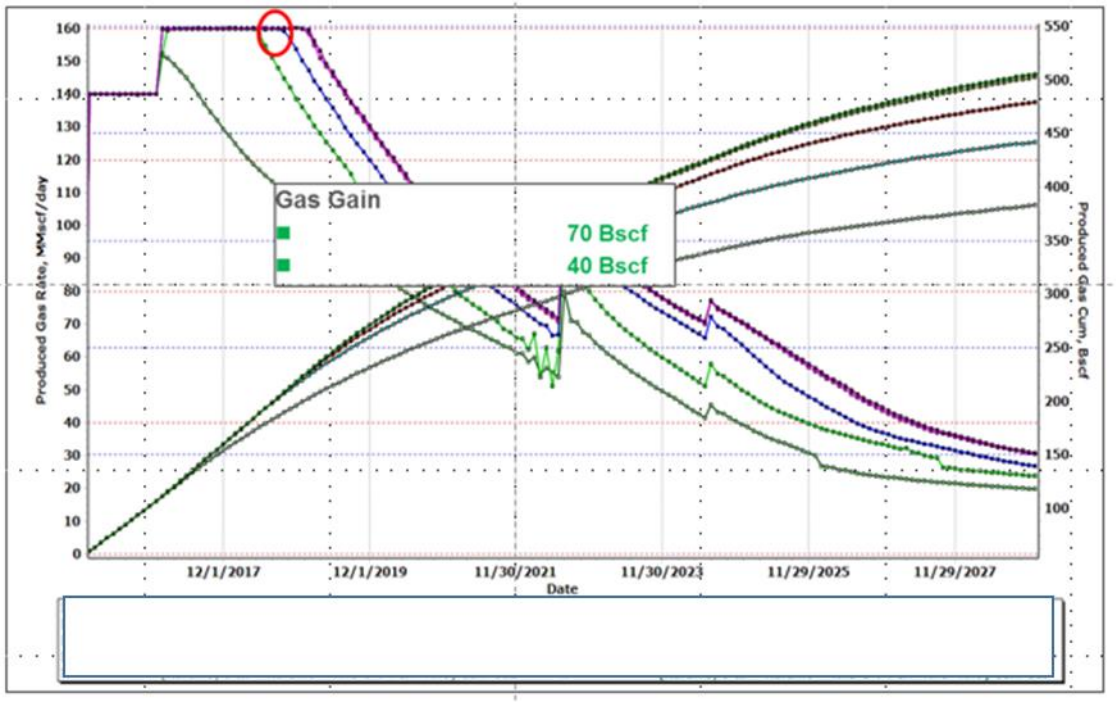
- X gas field was discovered in 2006 and it started production in 2014.
- It is Multi Layers gas reservoir (channel sands).
- Field development plan is to selectively produce the different sand layers in a timely manner to achieve a stable and steady production plateau.





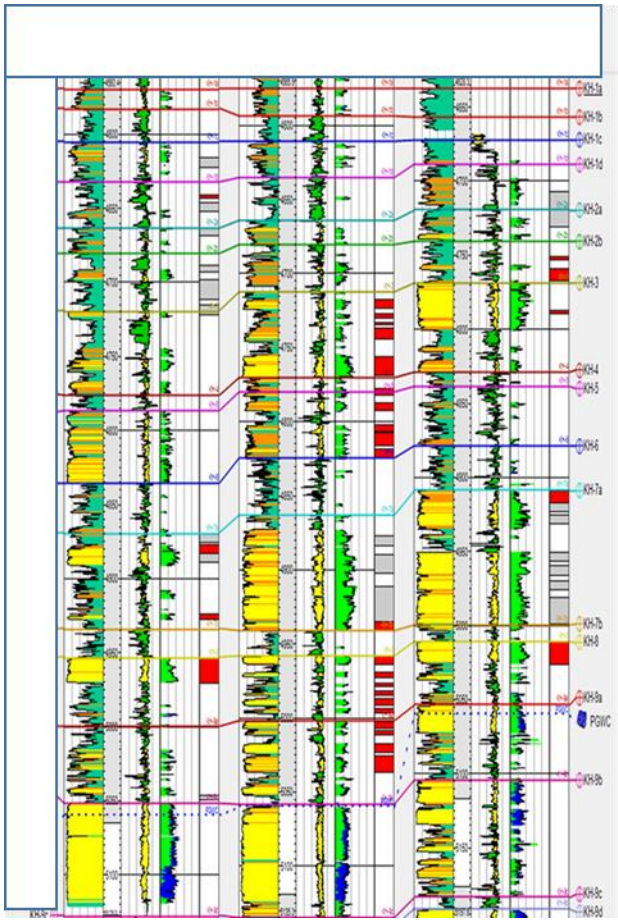
PRODUCTION DATA ANALYSIS

- Recent production data analysis confirmed the need for production enhancement action.
- Technical and economic analysis of the different options showed that the optimum approach was to add perforation in some of the wells.



ADD PERF OBJECTIVES

- Increase the well potential.
- Sustain well production beyond 2016.
- Take the advantage form the current high reservoir pressure
- To decrease the differential pressure between the already perforated intervals and the planned intervals.



Old perf

Proposed perf

CHALLENGES

1. Deep Wells (>5000m).

2. Relatively high H_2S & CO_2 Environment which constraint the cable options.

3. Reservoir pressure is relatively high (>6000 PSI).

4. New zones to be perforated were expected to have a pressure approximately 2500 PSI higher than the preexisting perforations.

5. Expected number of perforating runs per well was more than 30 (including equalization runs).

DETAILS of THE INTEGRATED APPROACH

Job Design include:

1. Gun Selection considering the well completion and the BH Fluid.
2. How to deal with deployment Challenges and Cable selection based on deployment simulations
3. Gun Lifting and Blown up simulations to optimize number of runs

Logging Well On paper sessions to ensure clear perf plan based on:

1. Job Design
2. Equipment Preparation steps
3. Job Execution steps

Close monitoring during the execution phase to calibrate the design parameters to ensure optimum operation steps

Objective: Reducing number of rune, keeping a safe load on the cable and also preventing gun blown up-hole.

JOB DESIGN: 1. SPAN ANALYSIS

Objectives:

- Identify the optimum Gun considering:
  - ➢Productivity
  - ➢Completion Limitations
- Get an estimation of the production rate for Lift simulations

Productivity Report

Completion

Well Deviation:	0	deg	Drainage Area:	31.42	acre
Form Top (TVD):	5076.0	m	Dietz Shape Factor:	31.62	
Form Bottom (TVD):	5082.0	m	Formation Height (TVD):	6.0	m
Borehole Diameter:	6	in	Completion Percentage:	100	%
Wellbore Fluid:	Gas		Perf to Form Top (TVD):	0.0	m
Fluid Density:	3.516	ppg			

Formation

Rock Type:	Sandstone		Formation Fluid:	Gas	
Porosity:	13.0	%	Gravity (air=1):	0.75	
Horizontal Permeability:	50.00	md			
Vertical Permeability:	5.00	md			
kd/k:	0.20		Pore Pressure:	7600	psi
Wellbore Damage:	8	in	Formation Temperature:	321	deg F

Perforating System(s)

Perf #	Loaded Length (m)	Phasing Angle (deg)	Shot Density /Open Perfs (spf/%)	Eff Shot Density (spf)	Crush Zone kc/k	Crush Zone (in)	Form Pen Avg (in)	Form Dia Avg (in)	EH Dia Avg (in)
1	6.0	60	6.00/100	6.00	1.00	0.50	4.72 *	0.60	0.38

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

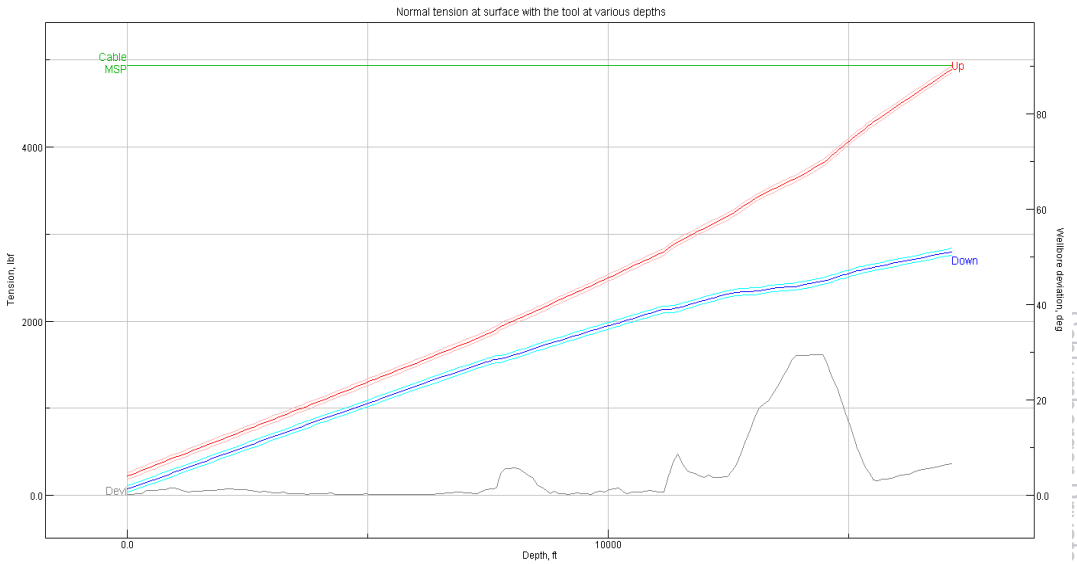
Perf #	Eff Skin	Darcy Skin	Perf Skin	Crush Zone Skin	Devi-ation Skin	Partially Open Skin	Non-Darcy Coeff (1/MMSCF/day)	Non-Darcy Skin	PR	PI * (MMSCF/day /psi)	Flow * Rate (MMSCF/day)
1	33.41	11.89	11.89	0.00	0.00	0.00	0.8965	21.52	0.37	0.01	24.011
OH	8.62	0.00	0.00	0.00	0.00	0.00	0.1395	8.618	1.00	0.02	61.771
OHdmg	26.64	5.20	0.00	0.00	0.00	0.00	0.7394	21.44	0.58	0.01	28.996

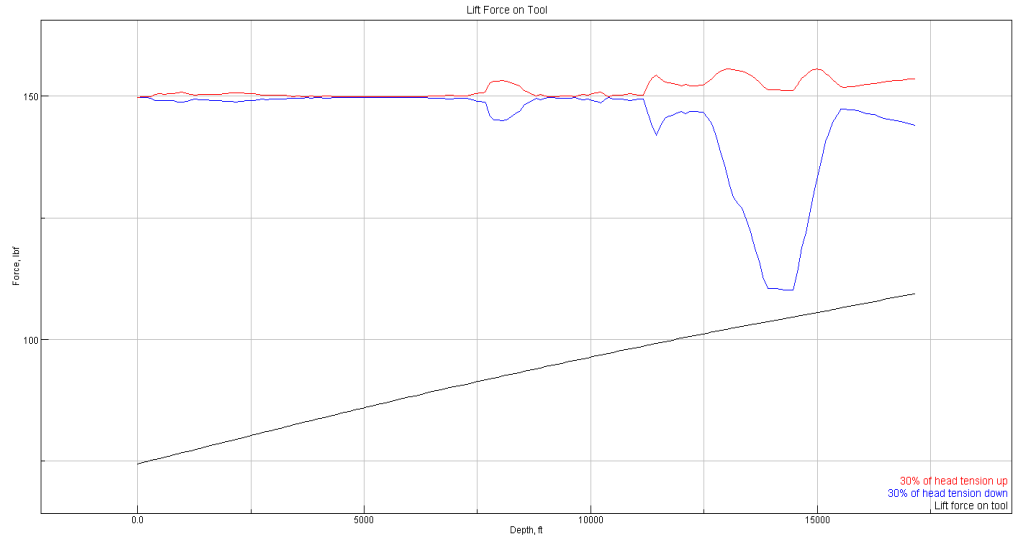
1. 2-7/8" HSD, PowerJet 2906, HMX

JOB DESIGN: 2. CONVEYANCE & LIFT CALCULATIONS

Objectives:

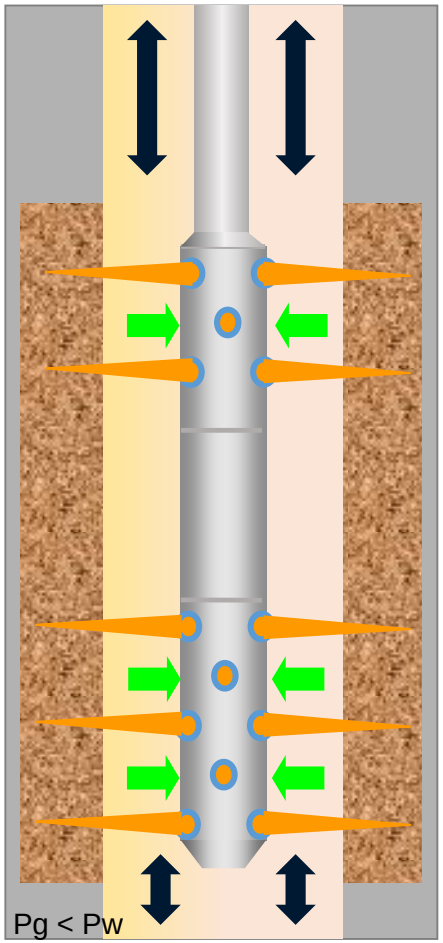
- Confirm RIH capability taking into consideration WHP and String Weight.
- Ensure that down hole and surface tensions will not exceed the maximum safe load of the cable Confirm that with the tool string and well depth we will not exceed the max safe load of the cable.
- Estimate the lift force following the add perf and confirm if it will be within the acceptable range or not.





JOB DESIGN: 3. GUN SHOCK SIMULATION

- When Perforating the detonation gas inside the gun interacts with the wellbore fluid, initiating the wellbore fluid dynamics effects.
- Perforating wellbore dynamics is driven by:
  1. Detonation gas pressure
  2. Wellbore fluid type and pressure
  3. Formation pressure
- The wellbore dynamics drives two processes:
  1. Pressure waves in the wellbore propagating up and down the wellbore at liquid's speed for sound. (Produce gun shock forces)
  2. Fluid flow between the reservoir rock and the wellbore. (Cleaning the perforation)
- Perforating gun shock can produce different types of damage:
  1. Ballistic shock can damage electronics
  2. Permeant deformation (bending)….TCP
  3. Gun jump that can cause unintentional breakage of the weak point.
  4. Gun Jump that can cause bird nesting



<u>We use software to predict wellbore dynamics and the associated gun-shock loads and all the other relevant aspects of perforating events (i.e wellbore de-pressurinzing & depressurizing by formation fluid)</u>

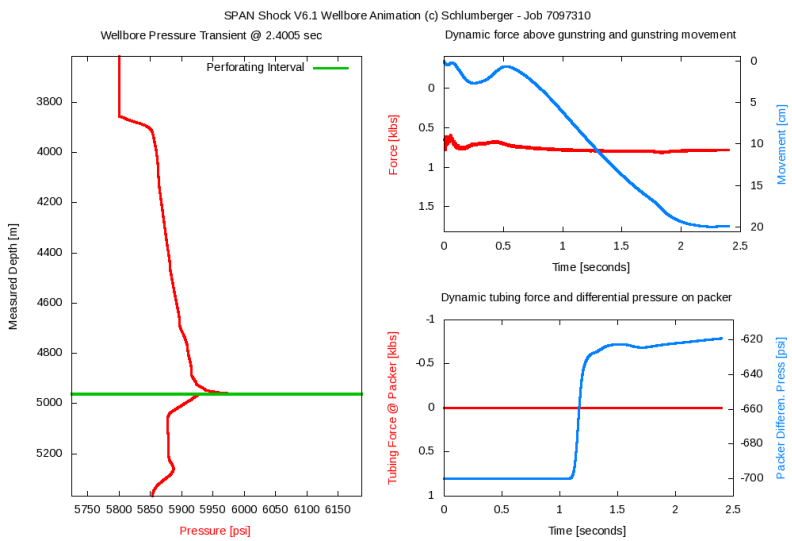
JOB DESIGN: 3. GUN SHOCK SIMULATION

SOFTWARE CAPABILITY:

- Coupled wellbore dynamics (fluids) & structural dynamics simulation
- Prediction of transient pressure around the guns / sand face* (DUB effect)
- DUB at the sand face (magnitude and duration) used to predict DUB cleanup, skin, expected productivity / injectivity, etc
- Prediction of guns movement, velocity, acceleration, tubing and packer loads, cable tension, peak load on the weak point
- GunShock is typically an issue with very high pressure wells and/or large guns, NOT an issue for most DUB jobs done with smaller guns or at lower pressure
- Software verified with an extensive database of perforating jobs (thousands)

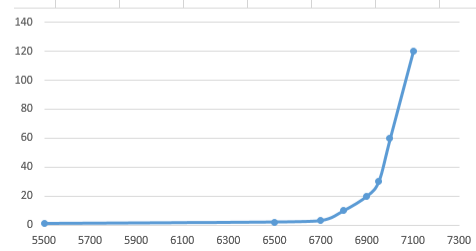
JOB DESIGN: 3. GUN SHOCK SIMULATION

Confirming the Gun Movement and Dynamic Load is within the limit



Finding relation between number of shots and wellbore pressure to confirm the safe perforation sequence

ssure	Shots
5500	1
6500	2
6700	3
6800	10
6900	20
6950	30
7000	60
7100	120



200md				
Runs	Gun	Shots	BHP	Movement
7094152	2"	2	6000	3
7094151	2"	2	6500	1.4
7094153	2.88"	2	6500	1.55
7094156	2.88"	3	6700	1.1
7094171	2.88"	10	6800	0.9
7094157	2.88"	5	6900	0.7
7094158	2.88"	6	6900	0.7
7094159	2.88"	10	6900	0.75
7094165		20	6900	1.5
7094168	2.88"	30	6950	1.4
7094167	2.88"	60	7000	1.1
7094166	2.88"	120	7100	1.1

RESULTS

- Safely and successfully Completed the Perforation Campaign and achieved the production targets.
- Changed the equalizing strategy from 1 & 2 shots to 10 ft/1 SPF which helped to have a better handling of the reservoir heterogeneity
- Come-up with
- Reduced the number of runs from 33 (Equalization & Main) to 21 (Equalization & Main)

Plan

Gun Type	Net ,m	Equalization Shot Depth	Gun Type
2 7/8" Power Jet, HSD, HMX, 6 shot density, 60 Phasing.	6	Not Required	2 7/8" Power Jet, HSD, HMX 1 SPF and 2 SPF
	6	4979	
	9	4967	
	4	4963	
	5	4947	
	5	4938	
	12	4924	
	8	4901	
	2	4891	
	3	4886	
	6	4876	
	66 m	10 runs 1 SPF + 10 runs 2 SPF	

Actual

Gun Type	Net ,m	Equalization Shot Depth	Gun Type
2 7/8" Power Jet, HSD, HMX, 6 shot density, 60 Phasing.	6	Not Required	2 7/8" Power Jet, HSD, HMX 1 SPF and 2 SPF
	6	4979	
	9	4967	
	4	4963	
	5	4947	
	5	4938	
	12	4924	
	8	4901	
	2	4891	
	3	4886	
	6	4876	
	66 m	10 runs 1 SPF + 10 runs 2 SPF	

SUMMARY

- The used integrated approach proven success in perforating the high pressure gas wells in presence of high static underbalance conditions and It achieved the following:
  - Safe operation (no damage to equipment)
  - Optimize the number of runs (50% reduction in the equalization runs)

- BAPETCO has achieved good production gain from this add perf campaign.

- In similar environment (presence of depleted preexisting perfs); single and double shoots was not enough to achieve proper equalization between formation rock and wellbore. Relying on the reliable wellbore dynamics software, more realistic equalization strategy been used.

THANKS
& QUESTIONS