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MENAPS 2022

MIDDLE EAST AND NORTH AFRICA PERFORATING SYMPOSIUM

WIRELINE ORIENTED PERFORATION IN DEEP GAS WELL COMPLETED WITH FIBER OPTIC CABLE

MENAPS-12-22 **AUTHOR: Sayed Kamal "Falcon Oilfield Services"**

Agenda

- ❑ Objective Overview
- ❑ Well Completion
- ❑ Challenges of Tool availability, Design, and Testing
- ❑ Testing the Oriented Tool in test well “Huston – USA”
- ❑ Job Design and Planning
- ❑ Shaped Charges Loading Density and Phasing
- ❑ Base test prior to the mobilization to well-site
- ❑ Job Execution
- ❑ Integrated Interpretation Data
- ❑ Conclusion

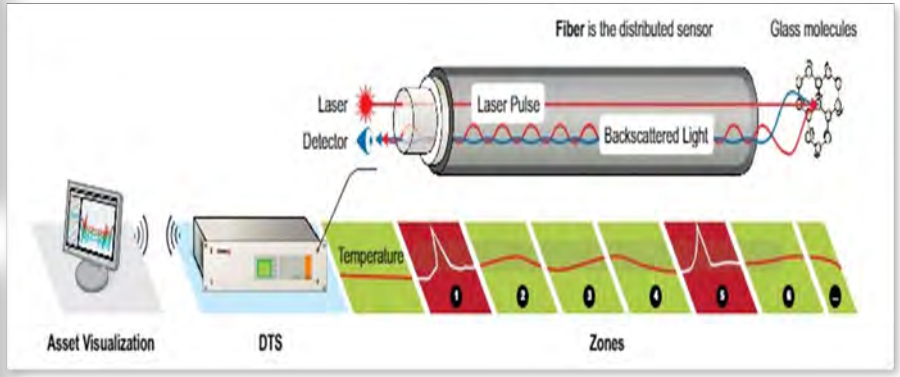
Objective Overview

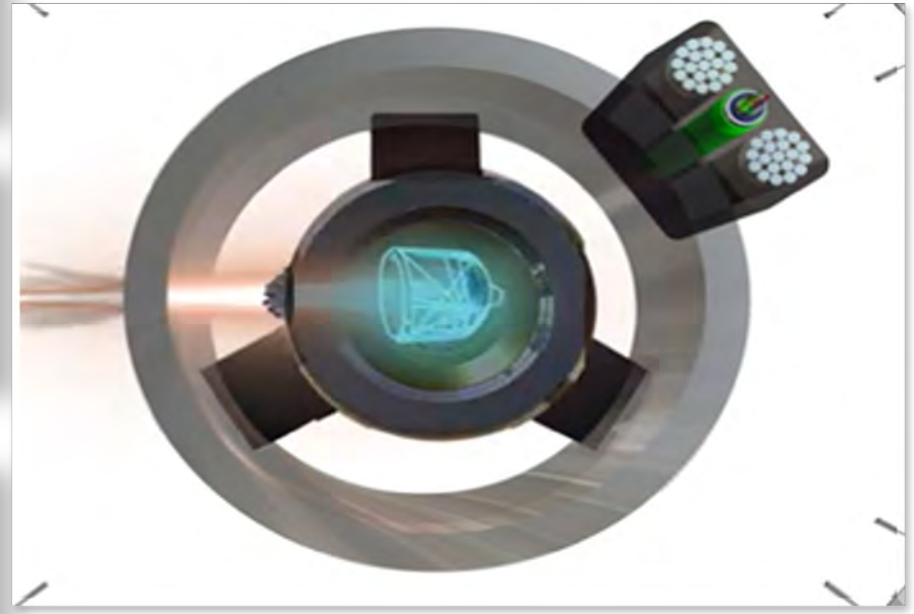
- Deep Gas well with tight formation completed with 4 ½" Cemented Casing and located external Acculocate **Fiber Optic** cable, connected to **DAS/DTS** decoding system on the surface

- Distributed Acoustics Sensing (**DAS**) and Distributed Temperature Sensing (**DTS**) is a technology to monitor the surveillance of the well integrity among other applications for the entire life of the well

- The well has been planned to perforate with a 2 7/8" HSD gun system, followed by Hydraulic Fracture Stimulation in 4 stages ensuring the integrity of the **Fiber Optic** Cable

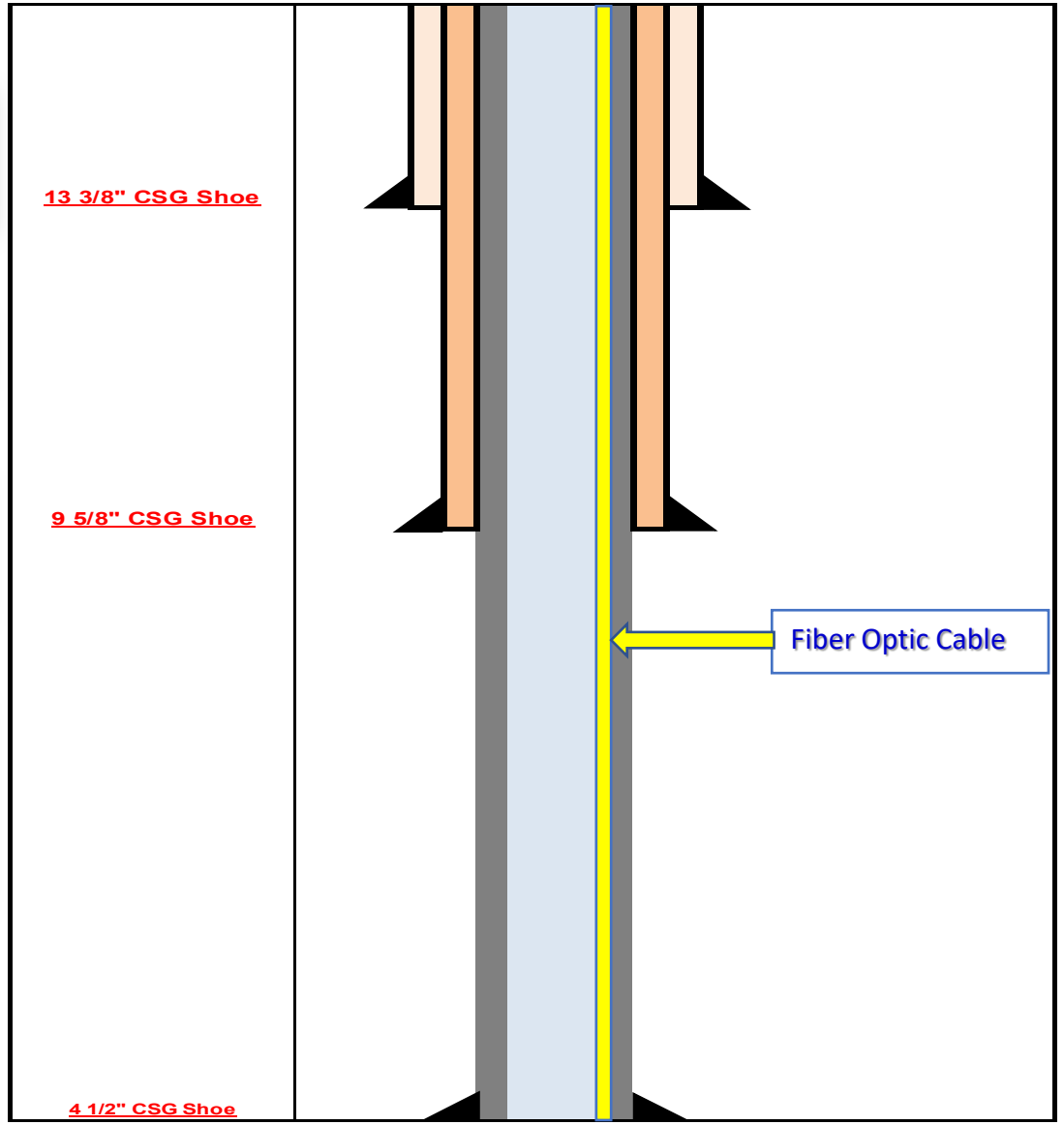
- The client in the Sultanate of Oman required an Oriented Perforating System to Perforate the well avoiding damage to the **Fiber Optic** Cable while perforating runs





Well Completion Details

- The well was completed with the **13 3/8”** Surface casing from surface to Casing Shoe
- **9 5/8”** Production Casing from Surface to Casing Shoe
- **4 ½”** CRM coated Casing from Surface to Casing Shoe @ x,xxx mBDF
- The Acculocate Fiber Optic cable was deployed and located outside the 4 1/2” Casing while running the completion string
- Modified the wellhead design to include feedthrough ports for the Fiber Optic cable



Challenges

- Survey in the market for Oriented Tool to carry 2 7/8” HSD gun system, as normally uses in 4 ½” casing completion and meets with a Frac design
- Limited time frame due to the Frac unit Plan & Schedule
- Availability of the Oriented System and Logistics to get it in the country on time
- Lack of experience to run such Service/Operation in our company
- Testing the Oriented system prior to shipment to the country
- <u>Design the Perforating Guns:</u>
  - Shaped Charges Selection
  - Loading Density and Phasing

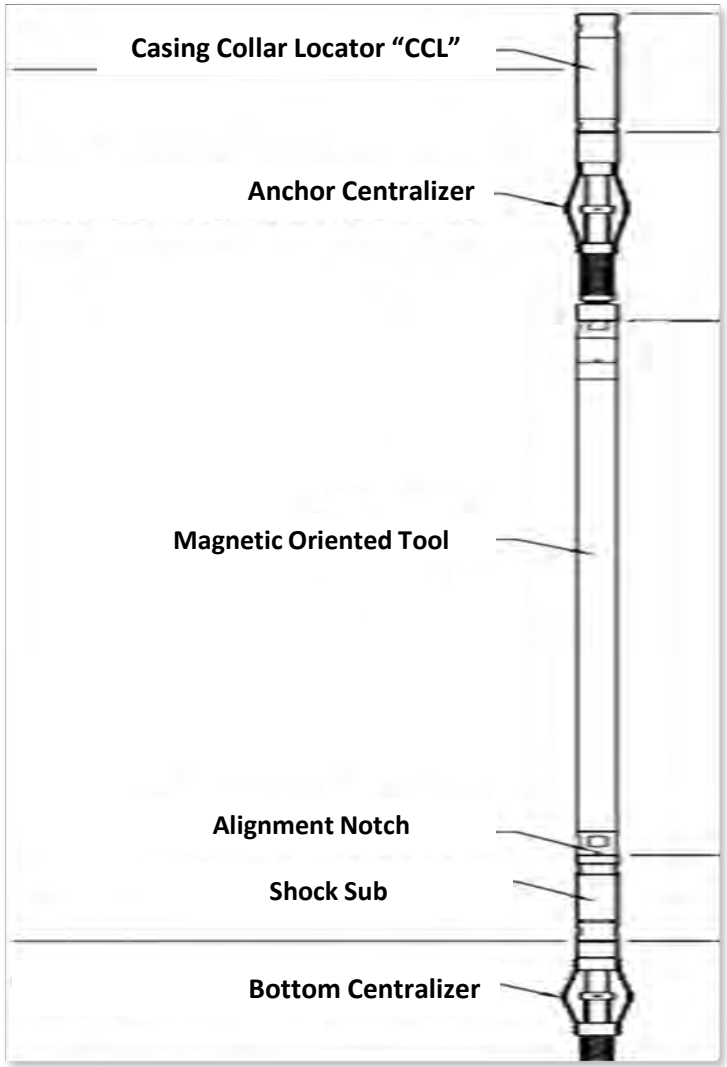
Survey in the market for Oriented Perforating Tool

- A survey in the market resulted in a 1 ¾" Magnetic Orienting Tool powered with Positive DC volt and capable to convey the 2 7/8" HSD gun system

- The oriented tool is ideal for perforating wells completed with deployed external cable behind the casing like a "Fiber Optic" cable and connected to acquisition DAS/DTS surface decoding system

- The oriented tool is physically connected to the top of Perforating guns and is typically comprised of CCL, Anchor Centralizer, Oriented tool, Alignment/Shock Sub, and then the perforating gun

- After the perforating gun has been Oriented away from the Fiber Optic cable, it will be shot/activated by sending a Negative DC Volt from the shooting panel on the surface



Operating Principle of Oriented Perforating Tool

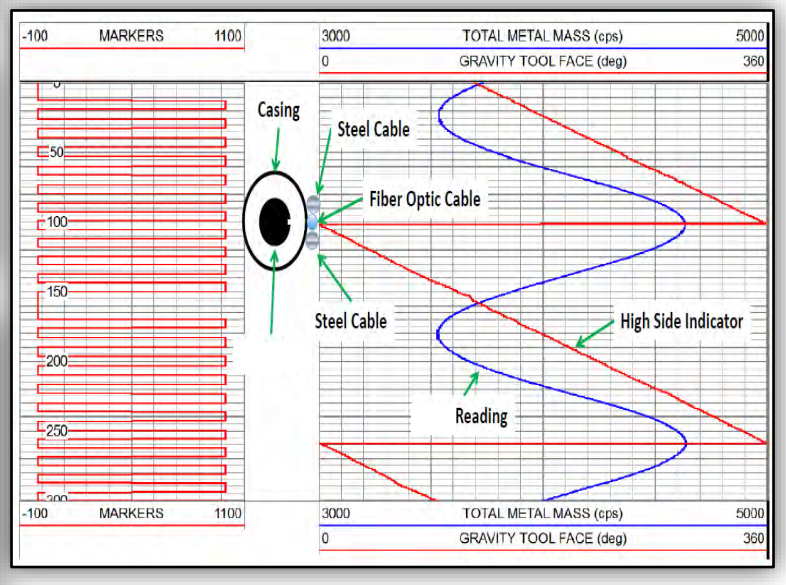
- The Oriented Tool is powered in three sequence modes by adjusting the Voltage and Current through Power Surface Panel

- Just the signal waveform appears, adjust the Red/Blue thresholds until getting the green light is illuminated in the telemetry window

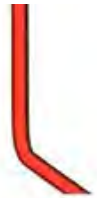
- The tool has an axial exciter coil that produces a uniform **Alternative Magnetic Field** in all directions and **Penetrates** the casing thickness

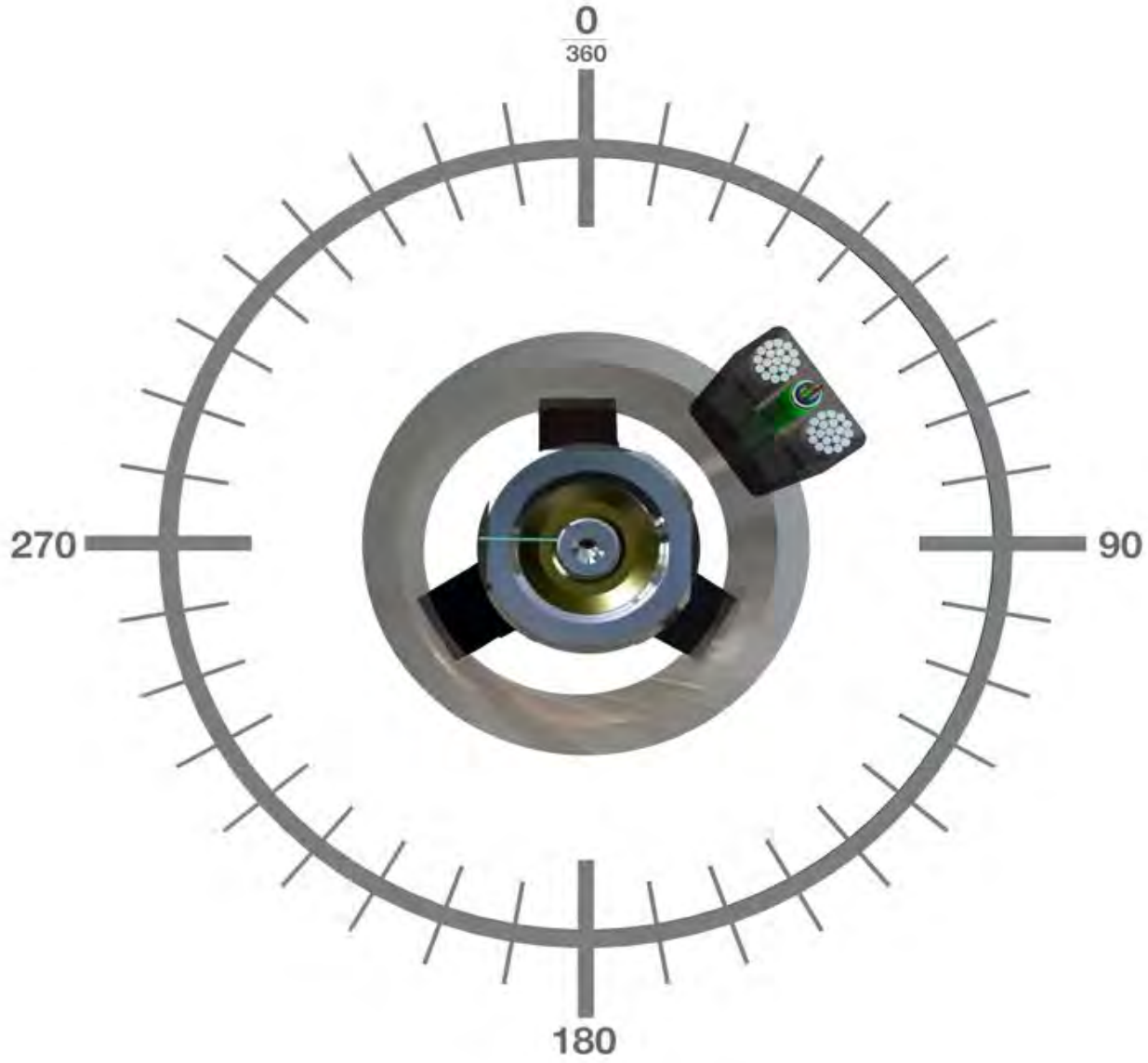
- The tool's directional receivers aspect below the exciter and measure the phase change between the Primary and Secondary magnetic fields while rotation of the tool

- The phase change is measured and used to generate a curve that is proportional to Metal Mass versus an Angular position to the tool
  - High Phase Shift means increasing in Metal Mass
  - Low Phase Shift means decreasing in Metal Mass



Oriented Perforating Tool Simulation





Availability of the Oriented Perforating Tools

- **Availability of the Oriented Tools and Logistics to get it in the country on time**
  Agreed with the tool's provider to get a Main and Back up tool-string with required spare parts in the county within 6 – 8 weeks plus the shipment time and informing the client about this plan

- **Due to the Frac unit Plan and Schedule, the time frame to get the tools in the country is very tight**
  An integrated team was established to finalize the agreement between all stakeholders to accelerate the processing and get the tools on time

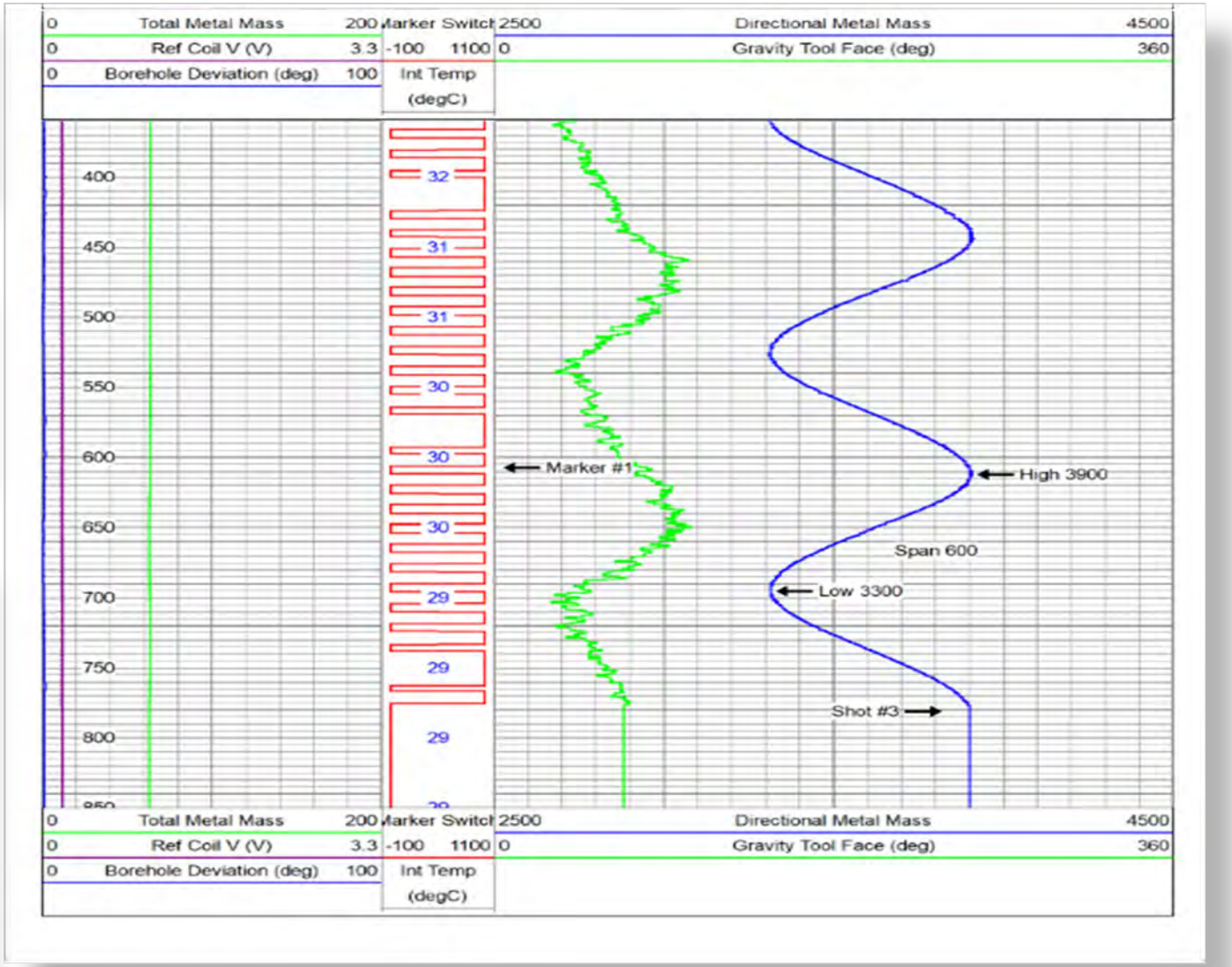
- **Lack of experience to run such Service/Operation and Testing the Tools**
  Assigned a Senior Field Engineer to be in the manufacturing facility for the training meanwhile, the client arranged a physical test for the Oriented Tools with a 2 7/8" HSD gun in a test well (Texas – Huston)

Testing the Oriented Tool in test well

- Testing the Oriented Tool with 2 7/8” HSD (4 SPF & 5 SPF) guns in test well hosted by the manufacture in “Huston - USA”

- Run a stationary mapping log to record the base line of casing Directional Metal Mass counts

- The high value of Directional Metal Mass (DMM) is 3,900 counts
- The low value of Directional Metal Mass (DMM) is 3,300 counts
- The Span between High and Low Values is 600 counts

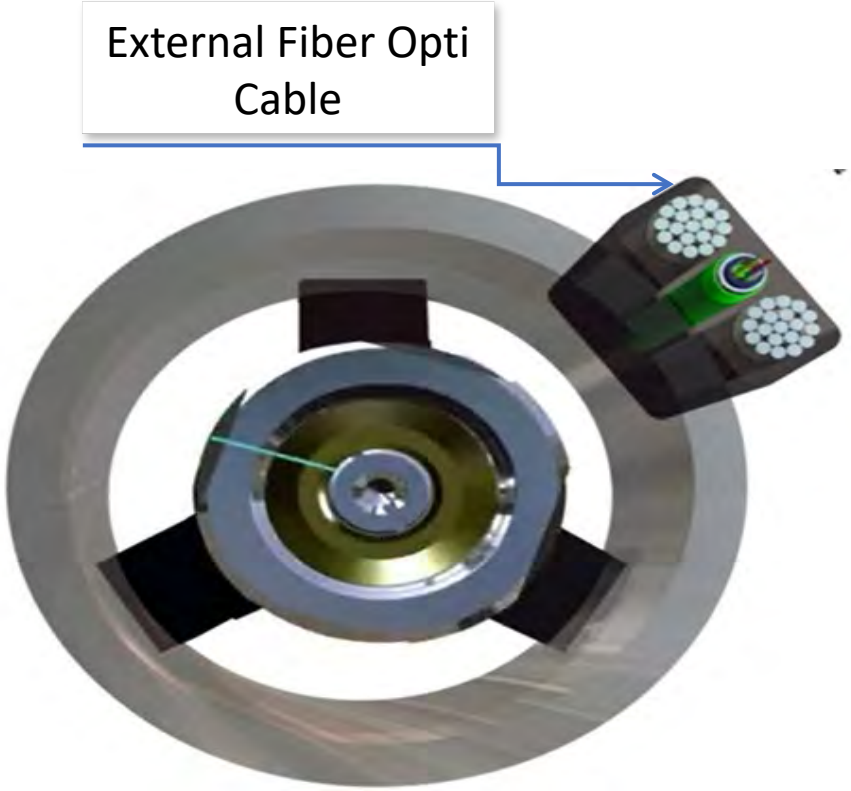


Job Planning and Design

The Client received two proposals from two different E-line service companies

- Proposal (A)
  - Run 1 11/16” Oriented Tool to identify the Fiber Optic cable
  - 2” HSD, 6 SPF, 60° phasing gun system
  - RDX Shaped Charges
  - Max 6.00 m Length per run
  - Successfully passed the test without damage to the Fiber Optic cable

- Proposal (B)
  - Run 1 3/4” Oriented tool to identify the Fiber Optic cable
  - 2 7/8” HSD, 6 SPF, 60° phasing gun system
  - HMX Shaped Charges
  - Max 3.00 m Length per run
  - Successfully passed the test without damage to the Fiber Optic cable



Oriented Tool Assembly with Perforating Gun

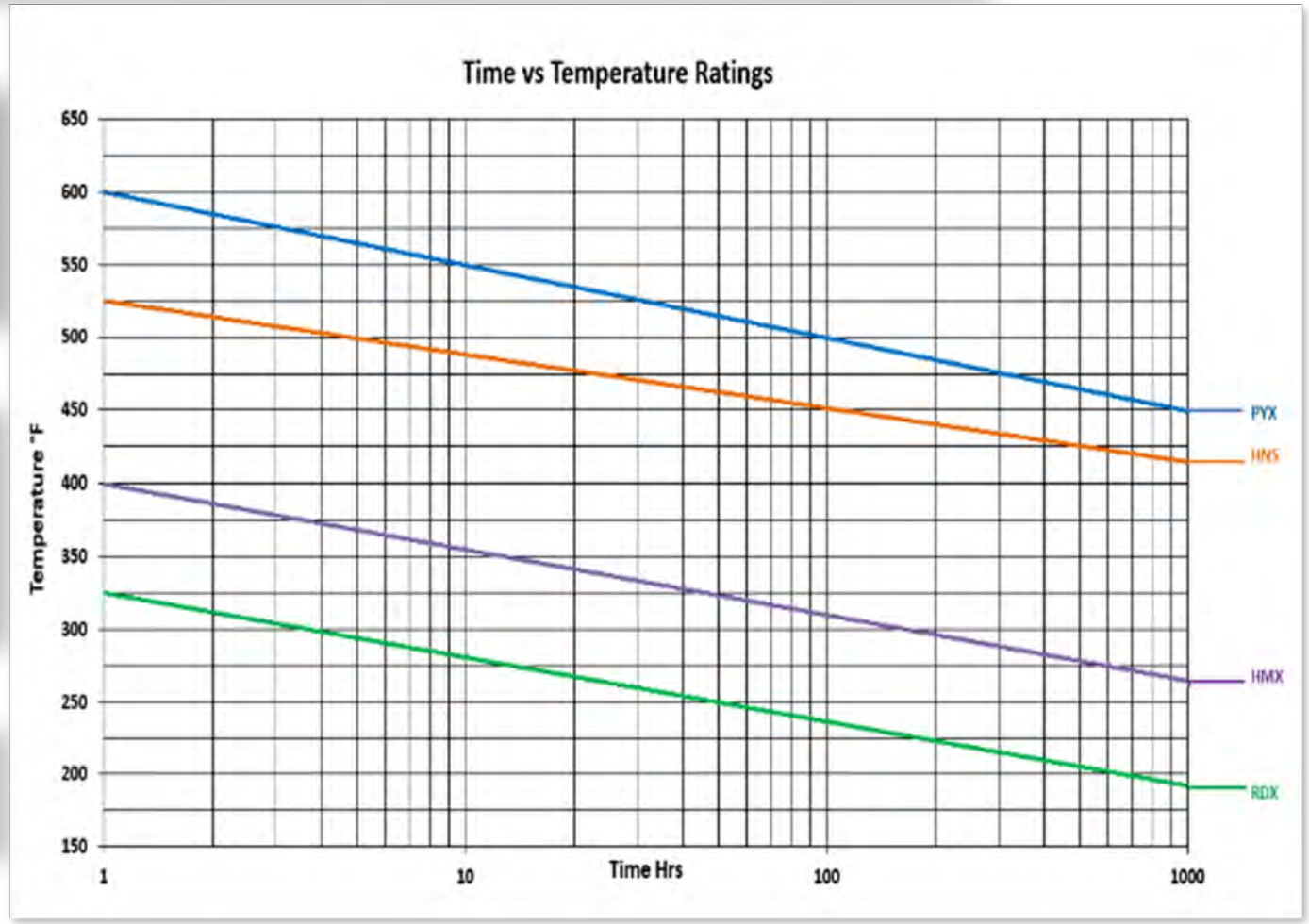
Design the Perforating Gun System

- Both proposals were reviewed by the client's Technical Team, and the final assessment concluded that **Proposal (B)** is the most suitable and applicable for the job, considering that:

  - Expect additional time downhole due to the performing of the Correlation and Mapping logs to detect the **Fiber Optic** Cable prior to activating the gun"

  - The well is a Tight Gas Formation and normally uses a 2 7/8" HSD gun system in 4 ½" casing completion, as it meets with a Frac design

  - HMX charges have been selected based on the Formation Temperature values



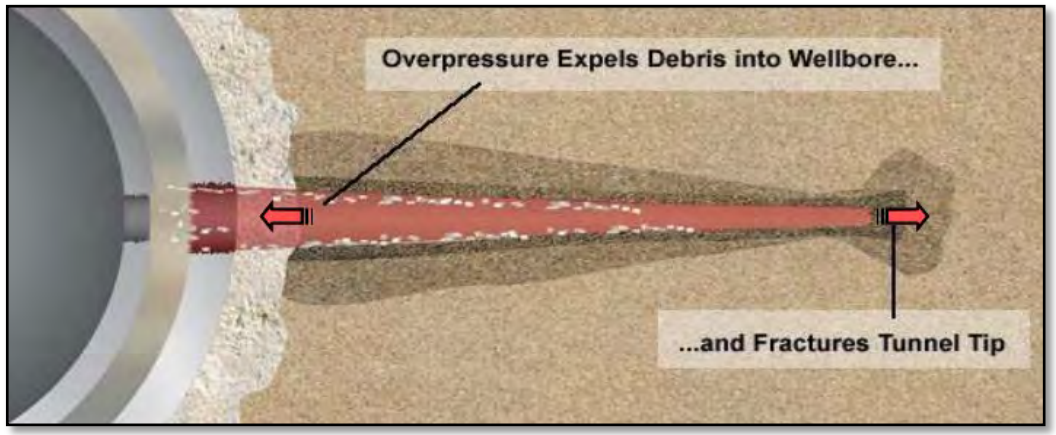
Shaped Charges Selection “Reactive Liner Charges”

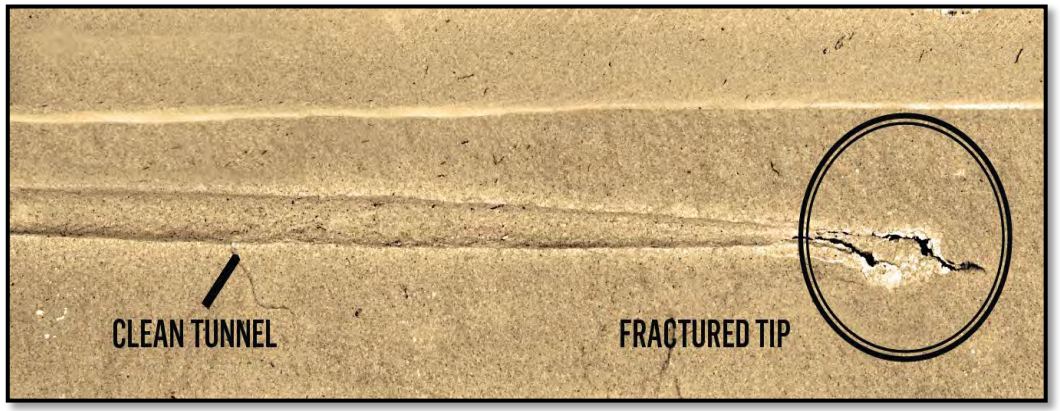
- Relative Liner Charges had been selected to perforate all the stages because of the success in Fracture Hydraulic Stimulation processing

- Reactive Liner charges generate a secondary reaction resulting debris-free and undamaged perforating tunnel along with the microfracture at the tunnel tip

- The secondary reaction leads to enhancing the injectivity and improves the stimulation processing

SPE-193254-MS & MENAPS-12-2016

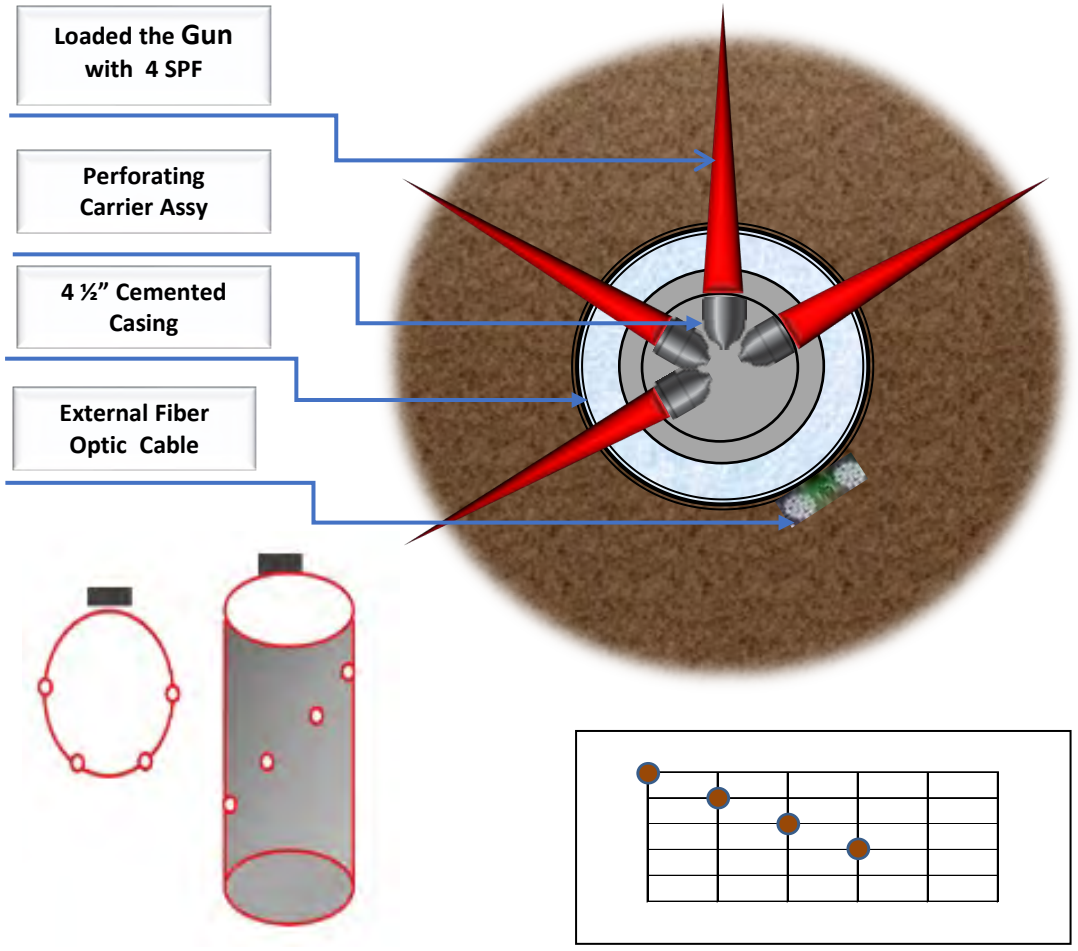




Shaped Charges Loading Density and Phasing

- Loading the guns with 4 SPF instead off 6 SPF to avoid damage the cable while shooting the gun
- Loaded 2 7/8” HSD Guns in one side of the gun by 4 SPF in 60 deg 6 SPF carrier
- Skipping 2 shots every 4 shots “Blanks” and aligned relatively to Oriented Perforating Tool

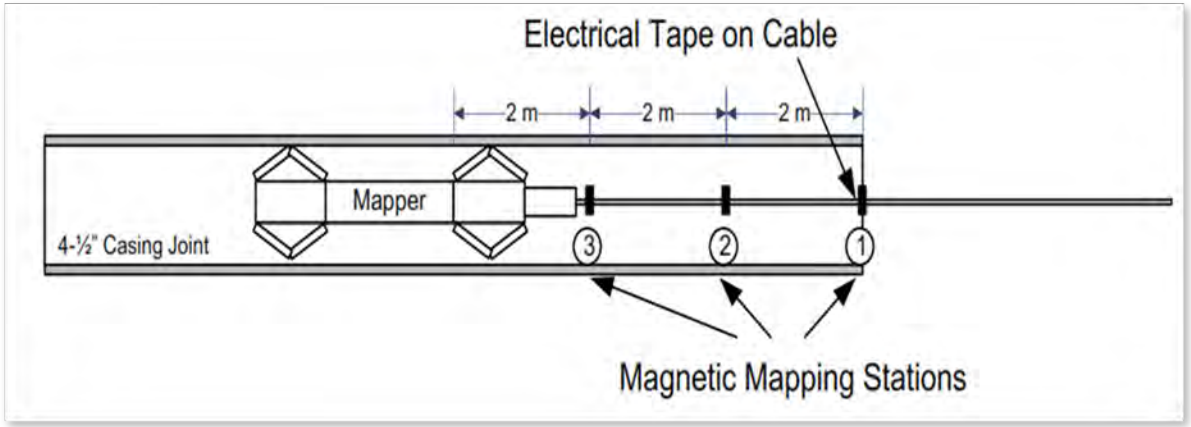
- The actual phasing of 4 shots in 0° - 180° deg (0°, 60°, 120°, 180° phasing)



2-7/8” HSD 15 gram Reactive Liner perforator

Base test prior to the mobilization to wellsite

- Performed a base test in the Falcon OFS workshop witnessed by the client's representative prior mobilize to the well site
- Recorded three stationary logs at different points of the casing with 2 m apart each
- Mapping the blank casing joint to record/determine the High/Low counts baseline without the Fiber Optic cable
- The Hi/Lo counts do not match with each other due to the manufacturing variation and metallurgy of the casing wall



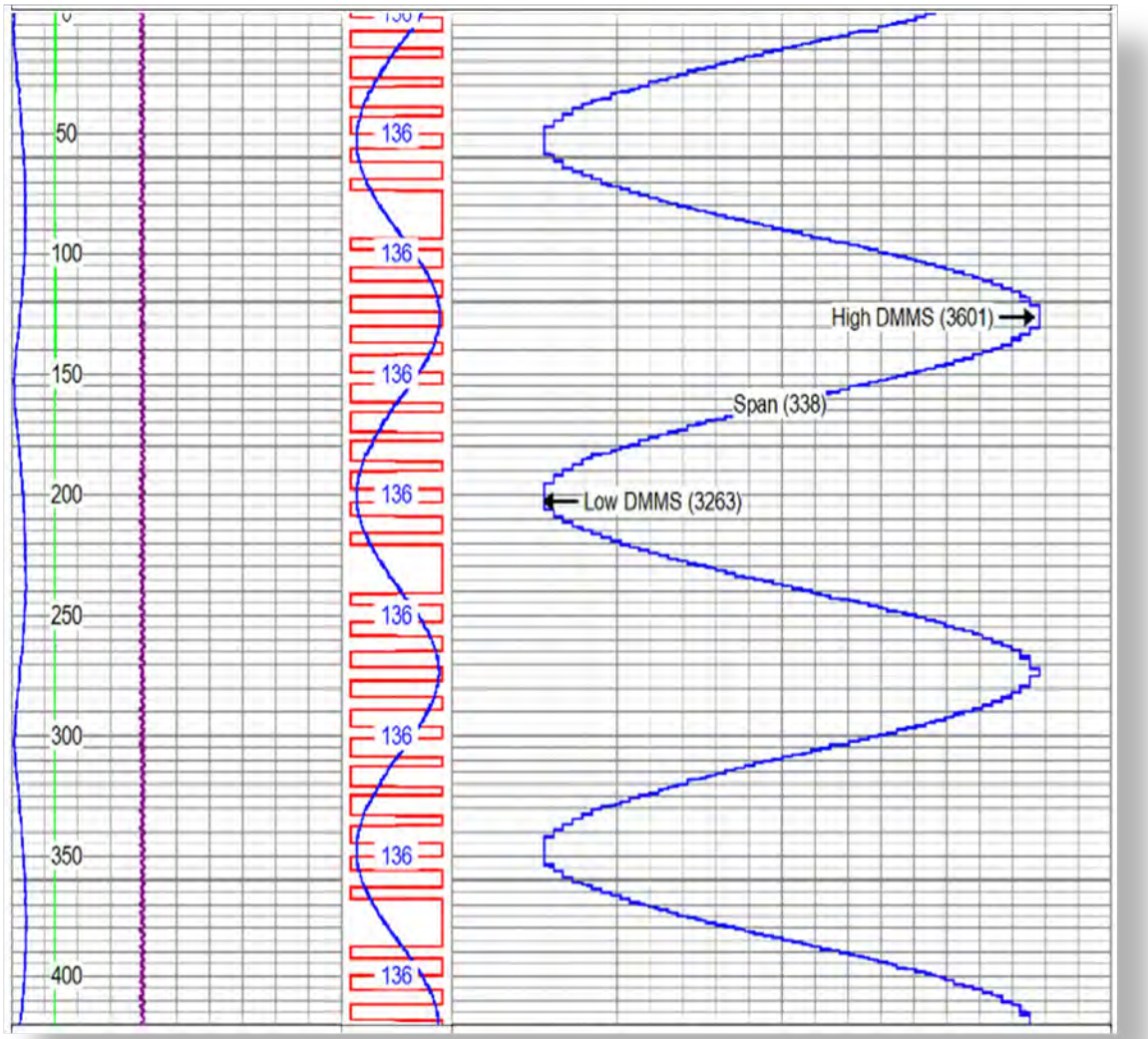
Station No	Min DMM Counts	Max DMM Counts	DMM Span (Max-Min)
1	3294	3346	52
2	3270	3340	70
3	3288	3334	46

Base test prior to the mobilization to wellsite

- Locate the Fiber Optic cable outer the 4 ½" CSG and record another stationary log to detect the Fiber Optic cable and record the High/Low counts as show in the picture and log

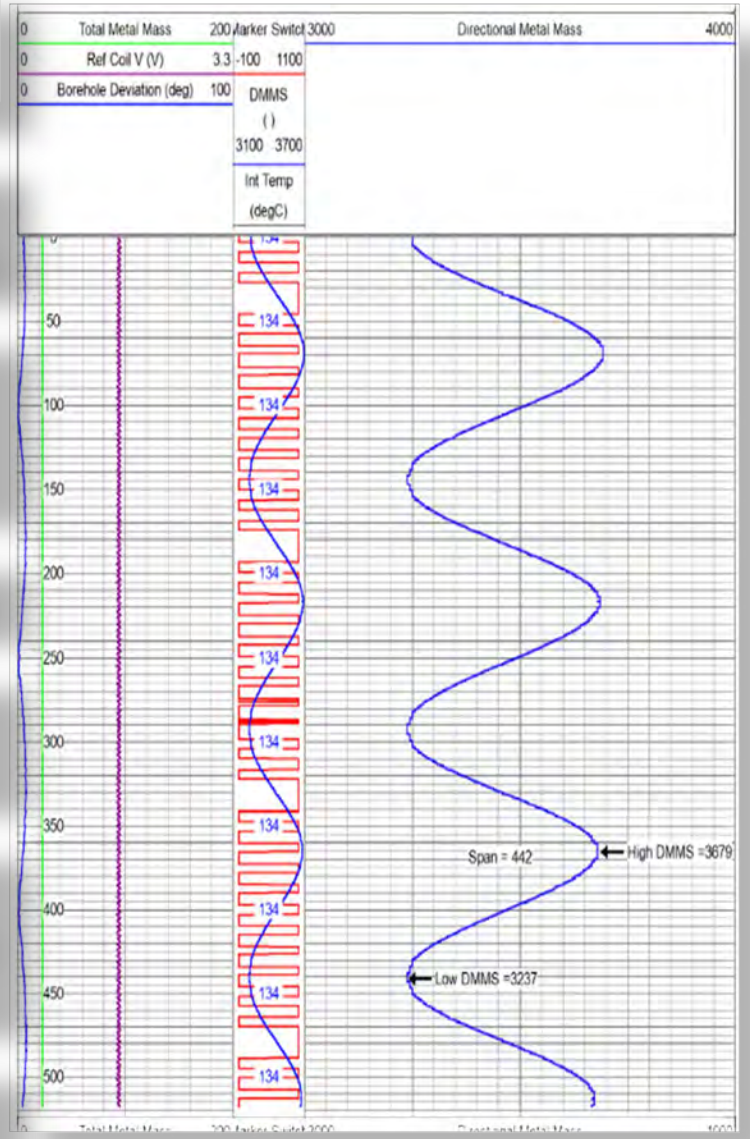
Identical 4 ½" CSG Similar to downhole Completion

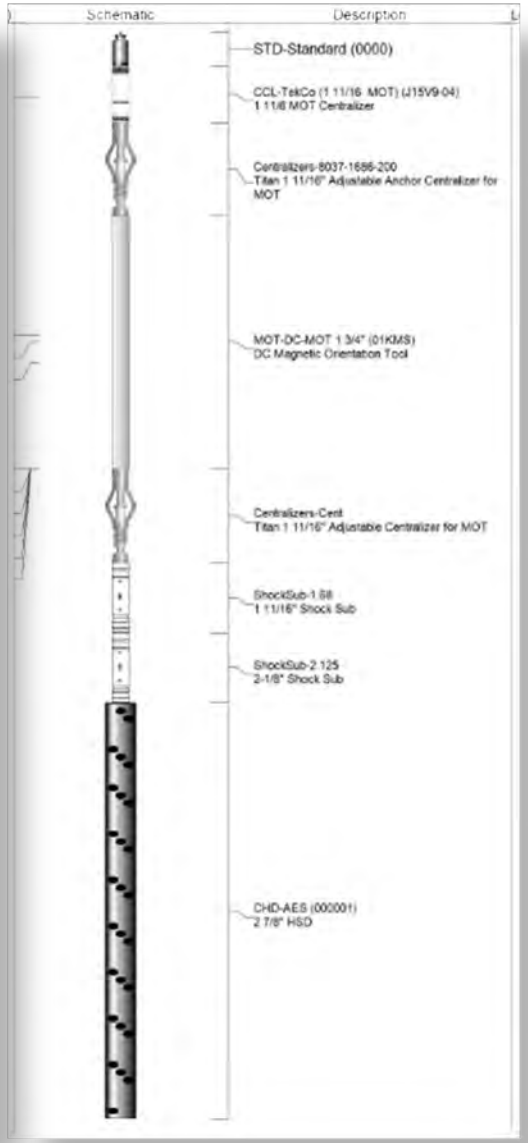
Fiber Optic cable located outer the 4 ½" CSG



Job Execution

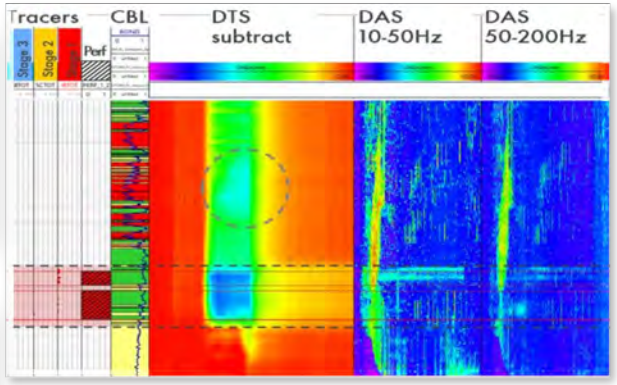
- Mapping the location of Fiber Optic cable prior to the perforation runs and record the downhole casing base line
- Make up the gun and connect with the Oriented tool, run in hole, correlate and position it on the target perforation depth
- Power on the Oriented tool, rotate and preform mapping stationary log with 3 complete cycle, stop at high DMM value, opposite to Fiber Optic cable
- LQC correlation and mapping logs by client's representative
- Activate the gun with monitoring the Fiber Optic cable Integrity / Functionality after shooting
- Perforate the first stage offline (Rigless intervention) targeting the bottom formation zone, Executed 6 successful runs of 2 7/8" HSD with 4 SPF 3.00 m each
- The rest of perforation runs (stage 2 to stage 4) were successfully executed with presence of FRAC unit



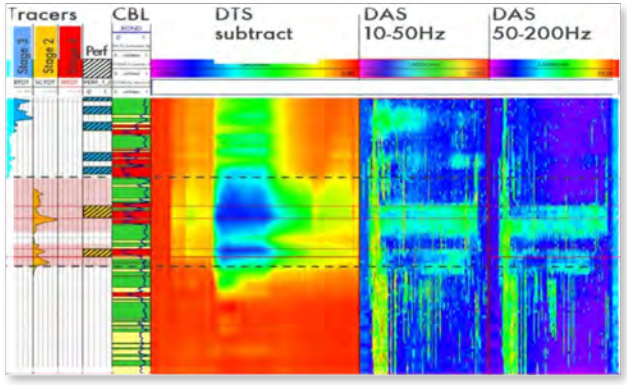


Integrated Interpretation Data DAS/DTS

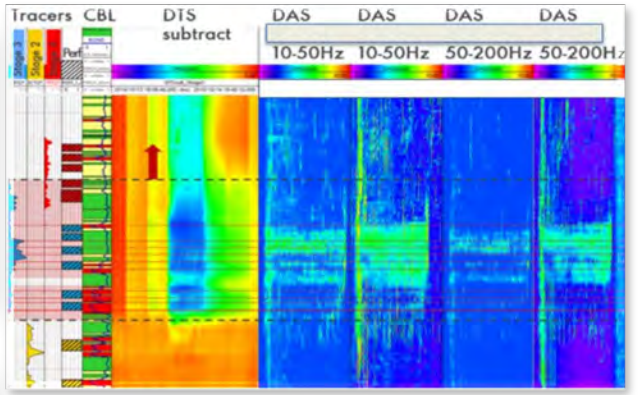
- The Fiber Optic cable integrity was in good condition and fully function after perforating each stage
- Monitor and Interpret the FRAC Stimulation analysis in real time helps to take the decision on time
- Available logs allowed the benchmarking of various information and understanding of the revealed queries of the reservoir behavior while FRAC operation
- The DTS and RA Tracer are confirmed each other, despite both techniques measuring slightly different "DTS detects total fluid, RA tracers measure only proppant"



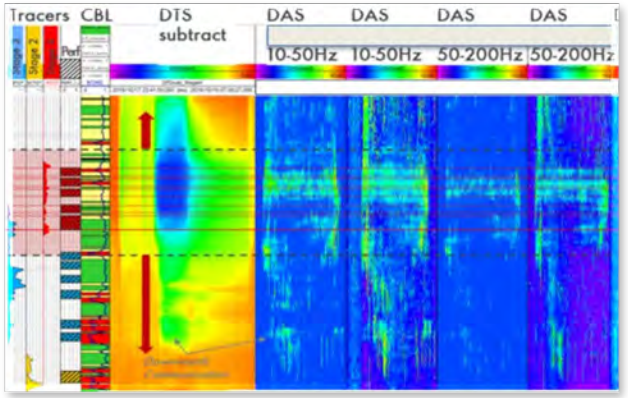
Stage#1



Stage#2



Stage#3



Stage#4

SPE-205275-MS & SPE-211001-MS

Conclusion

- The job was completed in 4 stages targeting two reservoirs formations A&B
- Perforate stage#1 (Formation A) offline with 6 successful runs with 3.00 m each (10 ft), Perforate stages 2,3&4 (Formation B) with the presence of FRAC unit with 15 successful runs 3.00 m each "few runs loaded with 2 m only"
- All Four stages were successfully Fracture Stimulation as per the FRAC Design
- The Fiber Optic cable was integral while all the Perforation runs and Frac operations
- Multi-Finger Caliper log performed after Perforation, Fracture and Milling all the isolated plugs between stages, the data did not record any abnormal readings and confirmed the casing integrity

Conclusion

- The installed Acculocate cable has 2 layers and ¾” wide, in order to enhance the Direction Metal Mass counts, there is a plan to install the 3 layers with the same wide ¾”, a base test done with new configuration in Q1-2022 and showed a significant improved 30 - 35% compared to the previous one

- The tool’s manufacturer R&D is working on developing the Oriented tool with a bigger OD size (2 ¾”) in order to carry 4 ½” HSD guns and perforate a 7” Casing

- The gun length is still one of the challenges as still limited with a 3.00 m (10 ft) gun per run due to gun shock limitation

- The test Arrangement, Procedures, and Operations are an excellent example of integration between all the stakeholders (Client, Service Company, and Tool provider) to make it successful

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Q&A