Development and Implementation of Side Mounted Gun (SMG) Systems for Intelligent Completions to Perforate Natural Gas Cap

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Introduction and Problem Statement

- Oil&Gas industry seeking to:
  - Extend profitability of marginal offshore oil reserves
  - Minimize costs of surface injection infrastructure for gas lift

- Major Operator looking for alternative intelligent completions to:
  - Reduce surface hardware on Production and Drilling Platform
  - Control commingled production of Lower Zones Oil Rim
  - Utilize Gas Cap zone for controlled natural lift
  - Minimize damage to Gas Formation

- Production Pipeline and Infrastructure designed for Gas
Side Mounted Gun (SMG) Perforating Solution

- Side Mounted Perforating Gun System identified as solution based on similar prior case in Norway
- Perforate Lower Oil Zones with Overbalance Shoot and Pull Tubing Conveyed Perforating
- Run Intelligent Completion String with multi zone isolation packers, gauges, flow control valves and side mounted guns across gas zone
- Perforate Gas zone underbalance with oriented guns
- Initiate natural gas lift for oil production to surface by actuating the Flow Control Valve of each zone
## Technical and Operational Challenges

### Technical Risks and Design Factors
- Design Trade-off for Gun and Tubing sizes with fixed Casing size
- Gun Support, Orientation and Locking with Respect to Tubing
- Control Lines Deployment and Clamping along Guns
- Length Tolerance Stack-Up and assembly Make-up
- Stretch/Compression of Tubing
- Alignment of multiple 20-ft Guns with Premium Tubing Thread Make-up

### Operational Environment and Constraints
- Drilling Plan changes impacting Casing size
- Equipment Delivery Assurance
- Arctic Weather Conditions
- Limited maneuvering Space on the Rig Floor
- No Man Riding at the Rig Floor
- Premium Tubing Connections can only be made up once
- Five Simultaneous Lifting and Hoisting Operations: Guns, Tubing and Three Control Lines
- No Dual Tubing Slips during RIH.
Product Development: Feasibility

- Determine optimum design geometry to optimize Gun and Tubing size for a given Casing ID.
- Optimization of Gun system (Size, Phasing, Density) using Perforating Analysis Software
- Concept Design and Basic Components
  - Locking and Orientation features between Tubing and Guns
Product Development: Design and Manufacturing

- **SMG Systems**
  - 9-5/8 Csg X 4.50 Tbg X 2.50 Gun X dual Hydraulic Delay Firing Head X 30 meters Total Length
  - 9-5/8 Csg X 4.50 Tbg X 2.50 Gun X Dual Electronic Firing Head X 100 meters Total Length
  - 7.00 Csg X 2.88 Tbg X 2.50 Gun X Dual Electronic Firing Head X 100 meters Total Length

- **SMG System Sub Assemblies**
  - Lower Gun Section
  - Middle Gun Section
  - Top Gun Section
  - Firing System Section
  - Intermediate Gun Support Clamps
Product Development: Qualification Testing

- 2.50-in Gun Swell-Bow
- 20-ft SMG Shop Sub-Assembly
- 20-ft SMG Section Tubing Integrity
- 20-ft SMG Section Control Lines Survivability
- SMG Firing System Fill Sub Pressure and Temperature Rating
Product Development: System Integration Test (SIT)

- SLB Cameron, TX Test Facility
- Participation of Field Personnel and Client Consultant
- Rig-Up and Deploy SMG system with 4x 20ft Guns and Dual HDF Firing System
- Evaluate two different RIH Procedures:
  - Pre-Job Preparation of all SMG Sections and alignment using Thread Timing Gauges
  - Rig Floor Alignment between Gun sections
- Confirm detonation transfer from firing head to bottom most gun
Product Development: Post SIT Improvements

- Changed SMG system from Top Lock to Bottom Lock
- Added Trapped Pressure Vent Valves to Firing Head Adapters
- Added Middle Supports to protect Tubing
- Added Hole Cover
- Enhanced Gun Lifting equipment
- Established alternate SMG assembly and running sequence
Running Sequence

RIH, and drop slips

Ensure mark on pipe is aligned with mark #2 on RT

Ensure mark on pipe is aligned with mark #2 on RT

Align FB no 2 with mark #1 on RT

Align and install lock pins in FB

Carefully guide gun through FB while slowly pulling up on tubing until bottom gun engages FB no 1.

Align FB no 2 with mark #1 on RT

Install “C” plate to cover hole

Install “C” plate to cover hole

Install bottom lock system

Install bottom lock system

Install / make up next assembly, remove bottom handling cap, install stabbing guide, position Gun 2 with stabbing guide into FB

Install / make up next assembly, remove bottom handling cap, install stabbing guide, position Gun 2 with stabbing guide into FB

Install “C” plate to cover hole

Gun 2 Install “C” plate to cover hole

Assy 3

Assy 1

Gun 1

Gun 1

Step 1

Step 2

Step 3

Step 4

Slowly RIH with tubing while slacking off on tugger, install middle gun and top footballs. Remove tugger, leave lifting cap in place

Slowly RIH with tubing while slacking off on tugger, install middle gun and top footballs. Remove tugger, leave lifting cap in place

Gun 2

Gun 2

Assy 3

Assy 1

Assy 1

Assy 3

Assy 2

Assy 2
Implementation: Well 1

- First Oil Rim well with in-situ gas lift
- 9-5/8 Csg X 4.50 Tbg X 2.50 Guns 6SPF SMG
- Two Oil Zones Perforated Overbalance prior to running Completion String
- Five Control Lines through SMG for two Flow Control Valves and two Downhole Gauges
- SMG total perforating interval 100 ft (Longest Interval to Date)
- Firing system with dual Electronic Firing Head
- Flawless rig-up and RIH operation of the SMG section and successful firing
- Production started as planned with all Valves and Gauges operational
Implementation: Well 2

- Second Oil Rim well with in-situ gas lift
- 9-5/8 Csg X 4.50 Tbg X 2.50 Guns 6SPF SMG
- 2.88-in 6 SPF oriented guns - solution to reduce risk of sand production in oil zone
- Three Control Lines through SMG for one Flow Control Valve and one Downhole Gauge
- New SMG design allowed to run 19 gun sections, 380 ft (longest interval to date)
- Successful rig-up and RIH operation of the SMG section
- Process safety measures were in place and tested prior to connecting well to the reservoir
- Gas zone cleaned and tested while oil zone was in delay mode (3 days)
Conclusions

- Side Mounted Gun Perforating systems have been developed and delivered successfully to achieve client objectives:
  - Produce oil rim using natural resources for gas lift with intelligent completion
  - Eliminate the need for additional surface equipment on a congested platform
- All technical and operational challenges have been addressed through seamless collaboration between the Engineering Center and the Field Location including Client Representative
- SIT and Design Improvement implementation were proven beneficial to achieve excellence in execution through the installation in two wells
- Safe, Efficient and Reliable deployment of long SMG intervals up to 380ft has been established for future oil-rim completions
- SMG Technology can be applied for Multi-Zone Perforating in Permanent Intelligent Completions
Thank You & Questions...