Implementation of a permanent well barrier across triple casing 7-inch X 9-5/8-inch X 13-3/8-inch casing

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Agenda

- Project Overview
- Operation challenges
- Pre job planning
- Engineering Solutions
- Execution and Results
- Rig time savings
- summary

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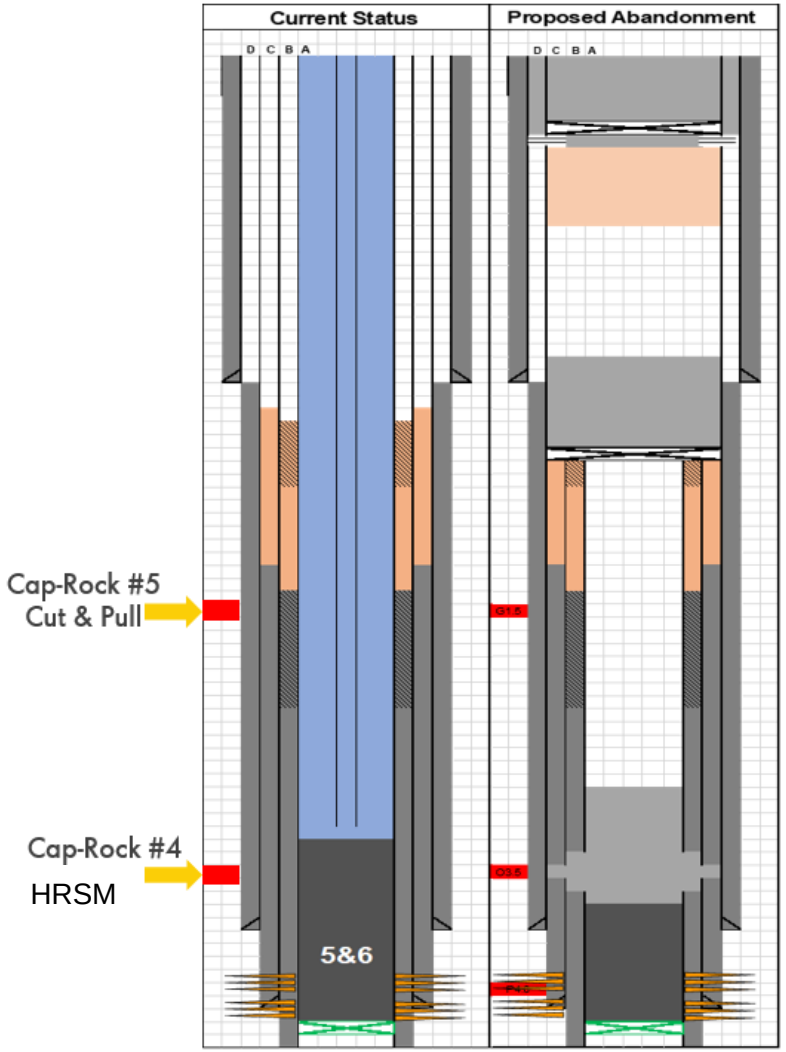
Project Overview

- Unique challenge to isolate three casing strings configuration for a well drilled in 1980.
- To provide a cap rock to enable zonal isolation across 7” x 9-5/8” x 13-3/8” casing.
- One of the many unique challenges were the A, B and C annuli cemented to surface together with centralizers.
- Section milling of dual casing was proposed as a solution to meet permanent reservoir isolation (cap rock).
- The High Ratio Section Mill (HRSM) technology was implemented for the remediation of the cap rock # 4
- Depth of Cap Rock was 5116 ft to 5188 ft



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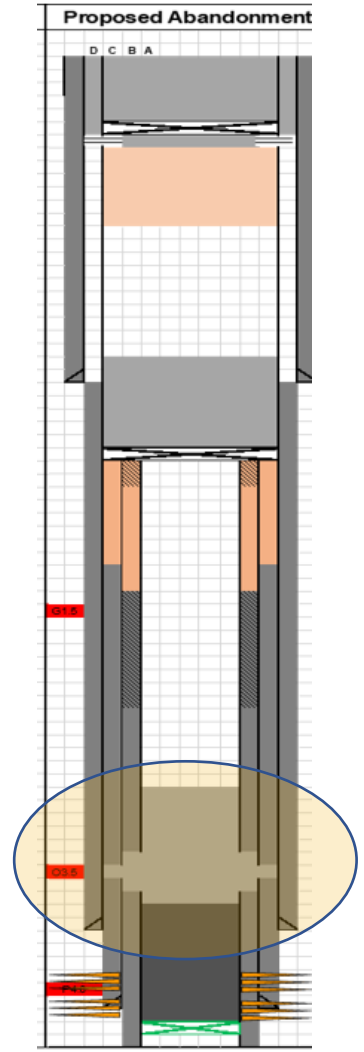
The Challenge

- Local Governing Regulatory Guidelines requires a barrier across regional caprock
- Conventional techniques requires 7” casing to be cut and pulled and then pilot milling to the required cap rock depth exposing the A-annulus, high cost and time consuming.
- HRSM to provide a cost-effective solution beyond conventional strategies.
- Variations of pore pressure requires multiple hydraulic setup based on 11.7 ppg to 14.7ppg mud weight.



Caprock to isolate 7” x 9-5/8” x13-3/8-inch casing

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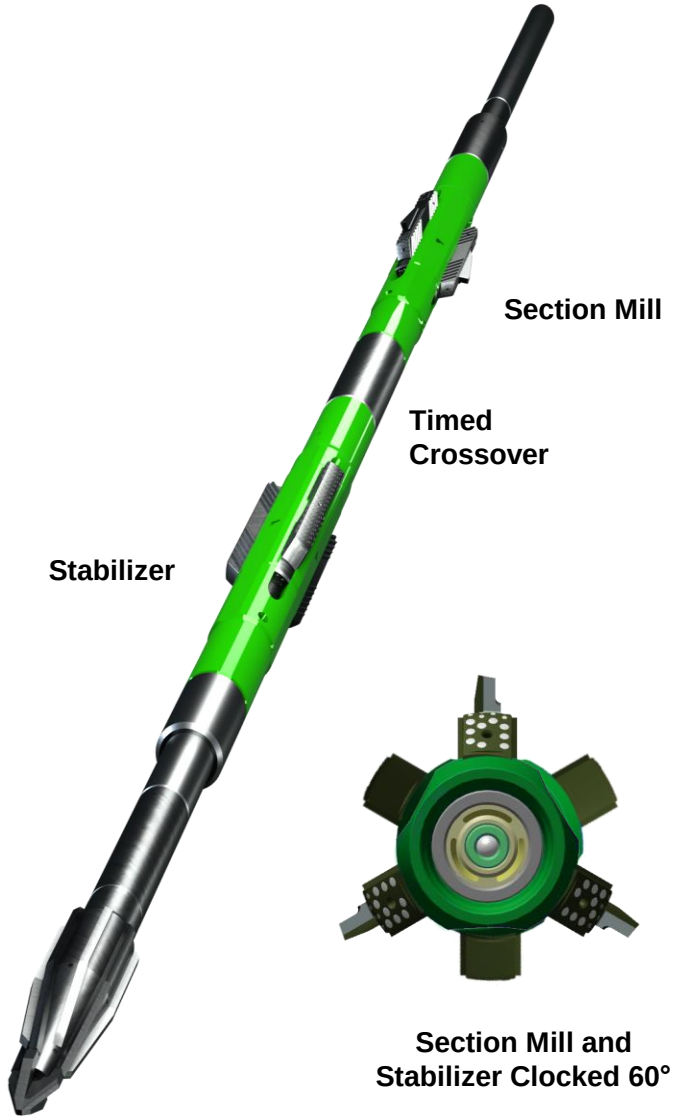
Engineering Solution

- **Implementation of new technology, the High Ratio Section Mill (HRSM)**
  - Drift inside the inner casing (e.g., 7”), and provides high expansion ratio (~80%) to mill the outer casing string (e.g., 19-5/8”)
  - Eliminates milling long inner string intervals
  - $aves time and trips
  - Reduces swarf handling

- **Features**
  - A High Ratio Expandable Stabilizer to reduce lateral vibrations
  - Time Cross over, oriented to achieve six-point stabilization for optimum milling performance
  - A High-Expansion Ratio Section Mill which includes the milling knives



Section Mill and Stabilizer Clocked 60°

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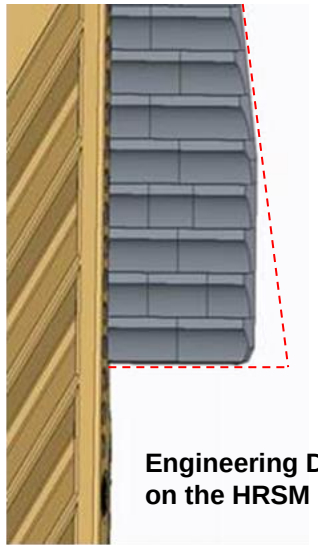
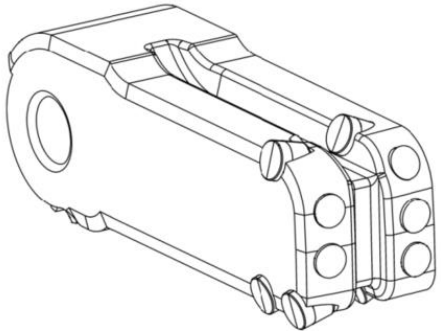
Engineering Design Changes

- Avoiding damage to the outer casing strings is key to job success
- Redesign of HRSM arms – flushed set to minimize damage on the 13-3/8” ID (internal casing wall) and ensure milling out couplings/centralizers
- Redesign of High Ratio Underreamer arms to cater for the 13-3/8” ID
- Outer milling, inner clean-out and inner milling intervals planned to account for bending stress
- Clearance for knives and arms activation and rathole for BHA length below HRSM



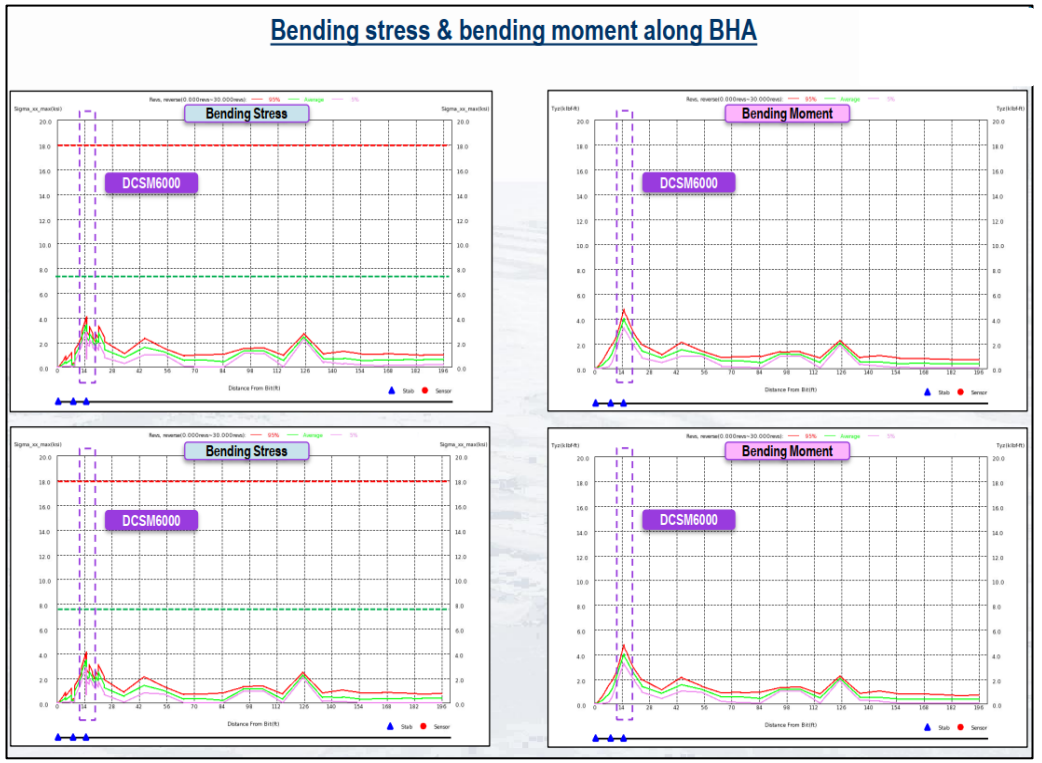
Engineering Design Change on the HRSM Arm Sets



Engineering Design Change on the High Ratio Underreamer Arm Sets

Pre-Job Planning

- Identifying shale zones for restoration for HRSM window planning
- Create Bottom Hole Assembly Design
- Understand Dynamic Behavior for milling to optimize parameters
- Various mud weights simulated for the optimum downhole hydraulics
- Multiple simulations performed for dynamic analysis and selection of the right BHA
- A parameter roadmap was created for the entire job



Hydraulics Summary for HRSM

MW	Minimum Operating Flowrate, LPM	Pressure Drop, psi	Max Operating Flowrate, LPM	Pressure Drop, psi	Max ECD
11.7ppg	1400	1044	1650	1492	14.36
14ppg	1270	1051	1600	1710	16.33
14.6ppg	1230	1025	1550	1672	17.01

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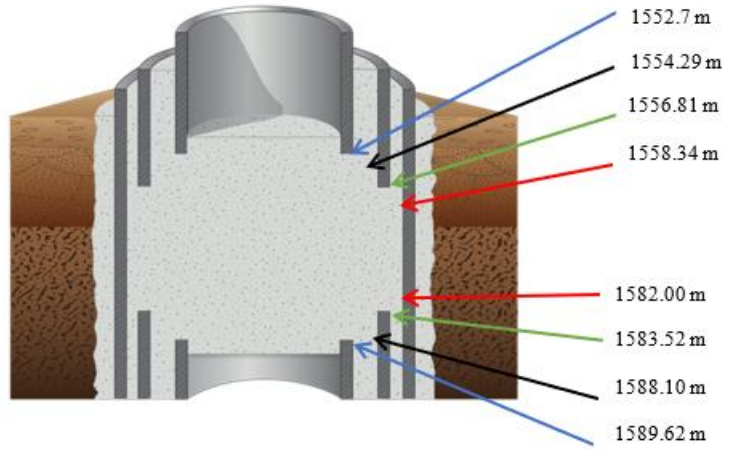
Window Planning

- Window plans are required to define all the milling and underreaming depths
- Factors into coupling depth to ensure milling depths are optimized to deal with couplings and centralizers



7” Casing Tally

Joint No.	Cent. Scr.	Length Ft.	Length ins.	Total Ft.	Total ins.	Joint No.	Cent. Scr.	Length Ft.	Length ins.	Total Ft.	Total ins.
Brought Forward						Brought Forward					
119		39	40			139	*	39	14		
120		39	38			140	*	39	24		
121		39	41			141	*	39	43		
122		39	37			142	*	39	38		
123		38	88			143	*	39	15		
124		39	41			144	*	39	33		
125	*	38	96			145	*	37	87		
126	*	39	36			146	*	39	20		
127	*	39	26			147	*	39	43		
128	*	39	37			148	*	39	27		
Total		392	80	5043	11	Total		391	44	5823	65
129	*	39	12			149	*	39	05		
130	*	39	25			150	*	39	33		
131	*	39	31			151	*	39	02		
132	*	39	36			152	*	38	65		
133	*	39	32			153	*	39	37		
134	*	39	38			154	*	39	28		
135	*	38	71			155	*	39	36		
136	*	38	74			156	*	39	37		
137	*	36	54			157	*	39	40		
138	*	39	36			158	*	39	29		
Total		389	10	5432	21	Total		392	12	6215	77

9-5/8” Casing Tally

Joint No.	Cent. Scr.	Length Ft.	Length ins.	Total Ft.	Total ins.	Joint No.	Cent. Scr.	Length Ft.	Length ins.	Total Ft.	Total ins.
Brought Forward						Brought Forward					
120	*	37	12			140	*	36	25		
121	*	39	53			141	*	37	93		
122		39	06			142	*	38	35		
123	*	36	41			143	*	38	62		
124	*	39	33			144	*	38	82		
125		37	68			145	*	37	70		
126	*	39	41			146	*	39	45		
127	*	39	35			147	*	36	14		
128	*	37	70			148	*	39	31		
129	*	39	46			149	B *	39	42		
Total		385	05	5040	15	Total		381	99	5808	49
130	*	39	25			150	*	39	45	5847	94
131	*	39	59			151	B *	39	23	5887	17
132	*	39	34			F.C.	B	1	85	5889	02
133	*	36	73			152	B *	39	06	5928	08
134	*	36	35			SHOE		1	75		
135	*	39	42								
136	*	39	23								
137	*	39	15								
138	*	38	37								
139	*	38	92								
Total		386	35	5426	50	Total		121	34	5929	83

Operational Steps	Without casing tally	With Casing tally
	meters	meters
Inner Window Start	1554.90	1552.77
Inner Window End	1588.10	1589.62
9-5/8 Cement Clean Start	1556.43	1554.29
9-5/8 Cement Clean End	1586.57	1588.10
Start Outer Milling	1559.48	1556.81
End Outer Milling	1582	1583.52
13-3/8 Cement Clean Start	1561	1558.34
13-3/8 Cement Clean End	1582	1582.00

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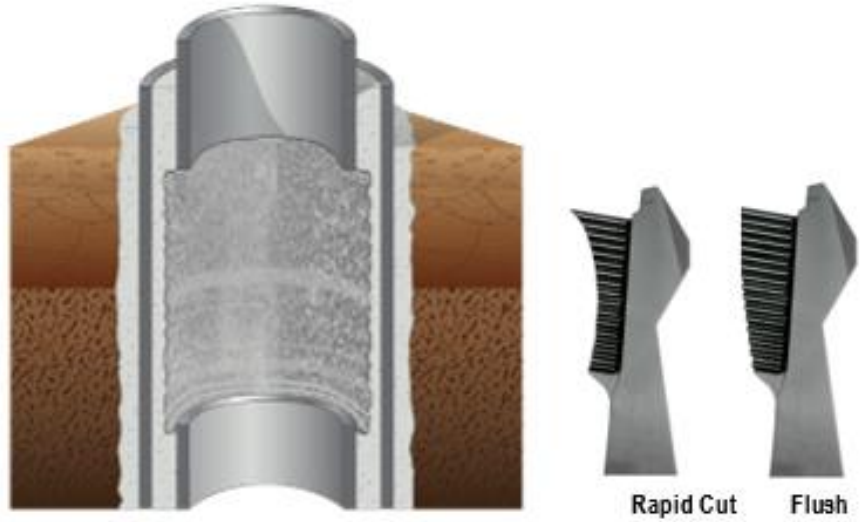
Detail Operational steps

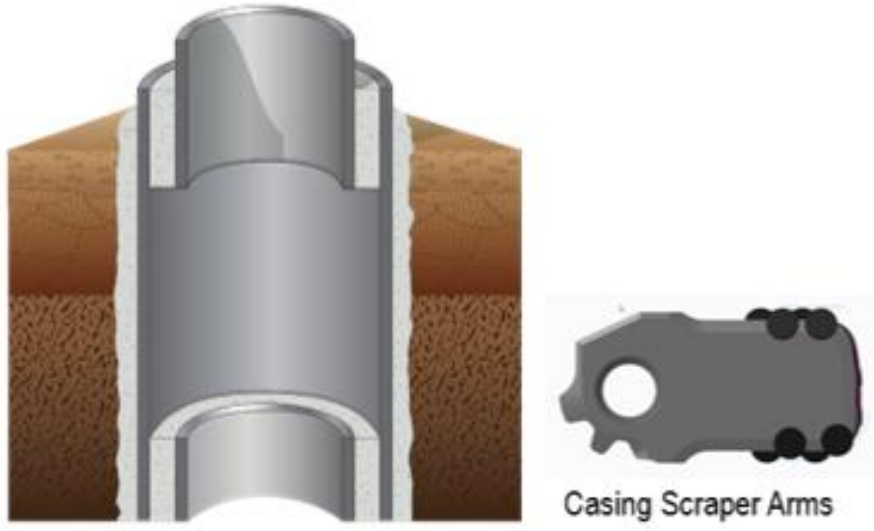
Inner mill the 7-inch casing using standard section milling technology, which deploys 2 different arm sets as follows:

- Rapid cut out knives.
- Flushed Knives design to minimize the damage on the internal diameter of the outer casing.



Inner 7-inch casing section milling with Rapid Cut and Flush design knives

Clean out cement sheath across the mill window of 7” casing (ID of 9-5/8” casing) using the high-ratio underreamer.



Scraping of 9-5/8-inch casing internal diameter with casing scraper arms

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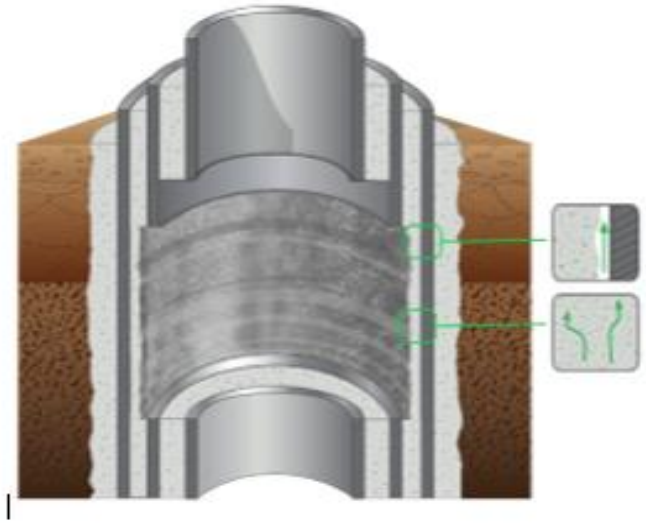
Detail Operational steps

Mill the outer 9-5/8-inch casing with High Ratio Section Milling:

- 1st run with standard knives
- Subsequent run with the newly designed flush knives to prevent the damage on the 13-3/8-inch casing

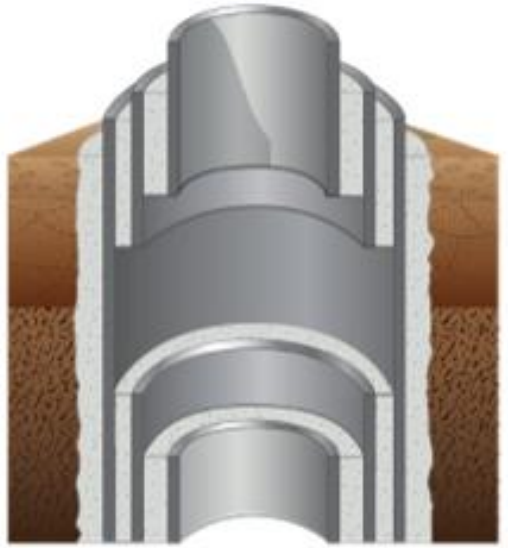


Section Mill the outer 9-5/8-inch casing

HRSM Knife

The final operation is to clean the ID of the outer 13-3/8” casing.

The high ratio underreamer is equipped with casing scrapper arms long enough to scrape the ID of the 13-3/8-inch casing



Scraping of 13-3/8-inch casing internal diameter with casing scraper arms

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Operational Results for Optimized Solution

Inner Milling

- 7-inch Section Milling was completed with a combination of cut out and flush knives
- Centralizers placed on every joint on every casing
- A limit of 15m per BHA was imposed to identify key wear patterns and optimized milling parameters
- Over 35m of milling interval was completed

Section Mill Arms Set Post Run

Cement Clean Out

- Subsequent run included an underreamer, performed in one single run
- Objective was to ensure that the internal diameter of the 9-5/8-inch is clean and will aid in the stabilization for the high ratio section mill
- Confirmation of no centralizers or cement stuck on the ID of the 9-5/8-inch casing

: Underreamer Arm Set with 8-1/2-inch Opening

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Operational Results for Optimized Solution

HRSM- Section Milling the 9-5/8- inch Casing

- The HRSM with cut out Knives was utilised for the initial cut out as planned followed by flush knives
- A limit of 15m per BHA was implemented to optimize milling parameters
- Total milling was completed with over 25m of 9-5/8” casing milled

Cement Clean Out

- The final run included the high ratio underreamer, performed in one single run.
- This verifies the ID of the 13-3/8-inch casing is completely clean with no centralizers or cement stuck before placing the final cement plug

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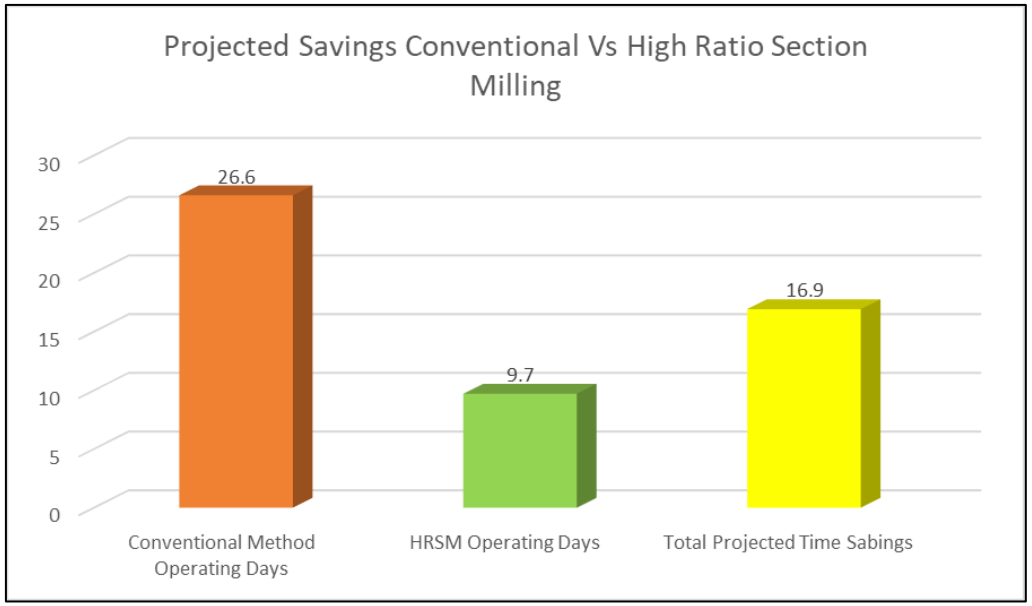
Conclusion

- Successful first global deployment of HRSM inside triple casing string
- The job was completed without any injury to personnel or process safety incident
- Zero NPT recorded and no waiting on equipment,
- Beat the performance benchmark by 32% against previous HRSM job
- Reduced the waste generation by 95% compared to conventional techniques



Saving client, a total of 17 days of operations time, equivalent to 4.4MUSD

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Lessons Learns

- Detailed planning for the job is critical: Knives and arm sweeps, conventional vs flush knives
- BHA design, tools and personnel requirements
- Performed SIT and QA/QC to minimize the possibility of failures as per client requirements
- Incorporate learnings from previous jobs: Avoid damage to outer casing, optimise surface parameters according to downhole conditions, maximize hole cleaning strategies and monitor swarf recovery
- Competent personnel during planning and execution
- Set clear expectation for performance – footage and ROP & don't be afraid to make the POOH decision
- Regularly maintain rig equipment; mud pump, TDS, shaker screens and metal swarf recovery system to ensure operations runs smoothly