BP: RHUM 2004 – 2005

COMPLETION, WELL KILL, PERFORATION

Deploying 2.19 g/cm³/18.28 lb/gal cesium formate brine in HPHT perforating operations brings significant HSE benefits and delivers productive wells with low mechanical skins.

The BP-operated Rhum field in the North Sea consists of three subsea development wells tied back to the Bruce platform. The field offered a number of development challenges, including:

- High temperature of 149°C/300°F, high pressure of 86 MPa/12,500 psi
- Lean gas reservoir fluid leading to high surface pressures (> 69 MPa/10,000 psi)
- Mildly sour environment with expected H_2S levels of 10 to 20 ppm and CO_2 levels between 4% and 8%

One of BP's requirements during the well completion phase was a minimum of one mechanical barrier and one fluid barrier while running the completions. This was seen as essential risk mitigation for safely running completions in a sub-sea environment. Only two clear fluids were capable of delivering the required brine weight of 2.19 g/cm³/ 18.28 lb/gal, namely cesium formate and zinc bromide. The HSE risks of working with zinc bromide were deemed unacceptable, leaving cesium formate brine as the only clear fluid matching the performance requirements.

Dynamic underbalanced perforating

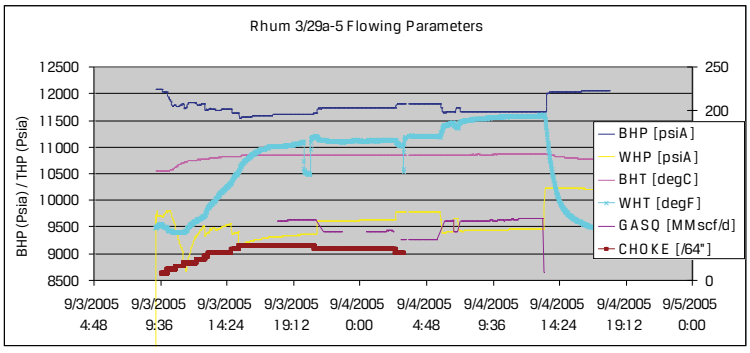
The first Rhum completion 3/29a-6 (SF-1) was perforated in a cesium formate brine kill pill using dynamic underbalance. The selection of drill pipe conveyed dynamic underbalance perforation and Schlumberger's PURE technique provided the best compromise for minimising HSE exposure and maximising productivity.

The perforation and isolation operations, including an inflow test of the barrier assembly, were completed in 6.3 days (0% NPT for the perforation operation) versus the planned time of 6.85 days. The well was perforated with 148 m of guns in a safe and efficient manner with only 4.2 bbls required to top up the string post detonation. No losses or influx of gas were observed post perforation.

The next Rhum completion 3/29a-4 (AF-1) was also perforated using the dynamic underbalance technique. This was a recompletion of the original appraisal well. Again the perforation and isolation operations were safe and efficient with the following highlights:

- The perforation and isolation operations, including an inflow test of the barrier assembly, were completed in 6.6 days (0% NPT for the actual perforation operation)
- The well was perforated with 46 m of guns in a safe and efficient manner, with no requirement to top up with fluid
- No losses or influx of gas were observed post perforation

Rhum 3/29a-5 start-up data



From well production testing it was concluded that perforating in dynamic underbalance with cesium formate brine matched well performance in the appraisal well DST after a standard underbalanced perforation. The kill pill has therefore been nondamaging and the perforation programme has achieved the desired productivity.

On-balance perforating with e-line

Operational issues forced the Rhum team to perforate the third well 3/29a-5 at balance in cesium formate brine using electric line. When brought onto production the well cleaned-up smoothly and quickly (see figure).

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The BHP and BHT indicate that flow was initiated with minimal drawdown and, after the initial slow ramp-up, the well cleaned up very quickly over an eight-hour period. After the initial clean-up period the well appeared stable. However, both gas production rate and WHP increased slightly over the remainder of the flow period, which was carried out at the maximum rate possible (72MMscf/day).

Once the well was put online at 150 MMscf/day to the production facility, both the WHP and production rate continued to increase gradually on a fixed-choke setting over the next several weeks, indicating the well was cleaning up over a long period.

Two pressure build-ups (PBUs) with reasonable data quality were collected and analysed on the well. The first PBU was taken after the initial clean-up flow. The table shows a comparison in KH and skin between the two PBUs using the same reservoir model. The total skin comprises of three components:

i) Mechanical skin (damage)
ii) Rate dependant (non-darcy) skin
iii) Frictional loss between the reservoir and the BHPG located 547 m/1,796 ft above

Comparison of pressure build-up data

	04/09/05	15/01/07
KH (md.ft)	9,646	11,483
Total skin (mechanical + non-darcy + friction drop to gauge)	+11.5	+10.8
Total reservoir skin (mechanical + non-darcy)	+8	+3
Maximum production rate (MMscf/day)	73	150

Conclusions

The results of the e-line operation show that the combination of cesium formate brine kill pills and on-balance perforating can deliver wells with low mechanical skins. The use of dynamic underbalanced perforating with cesium formate brine across the entire range of completion operations brings significant HSE benefits by:

- Allowing the well to remain in an over-balanced condition until the tubing hanger is landed
- Facilitating over-balance or dynamic underbalance perforating on drill pipe in long reservoir intervals
- Eliminating the requirement to bring hydrocarbons to surface during perforating operations
- Eliminating complicated surface rig-ups, rig modifications and multiple wireline or coiled tubing runs

Literature

Roy, A., Twynam, A., Parke, J., Morrison, A. and Downs, J.D: "An Evaluation of Perforating Techniques and Use of Caesium Formate Kill Pills to Maximise Productivity in HPHT Gas Wells and Minimise HSE Risk", OTC 19242, presented at the 2008 Offshore Technology Conference, Houston, Texas, USA, 5 – 8 May 2008.

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