



Petronas Carigali Kanowit 2012

Drilling and completion

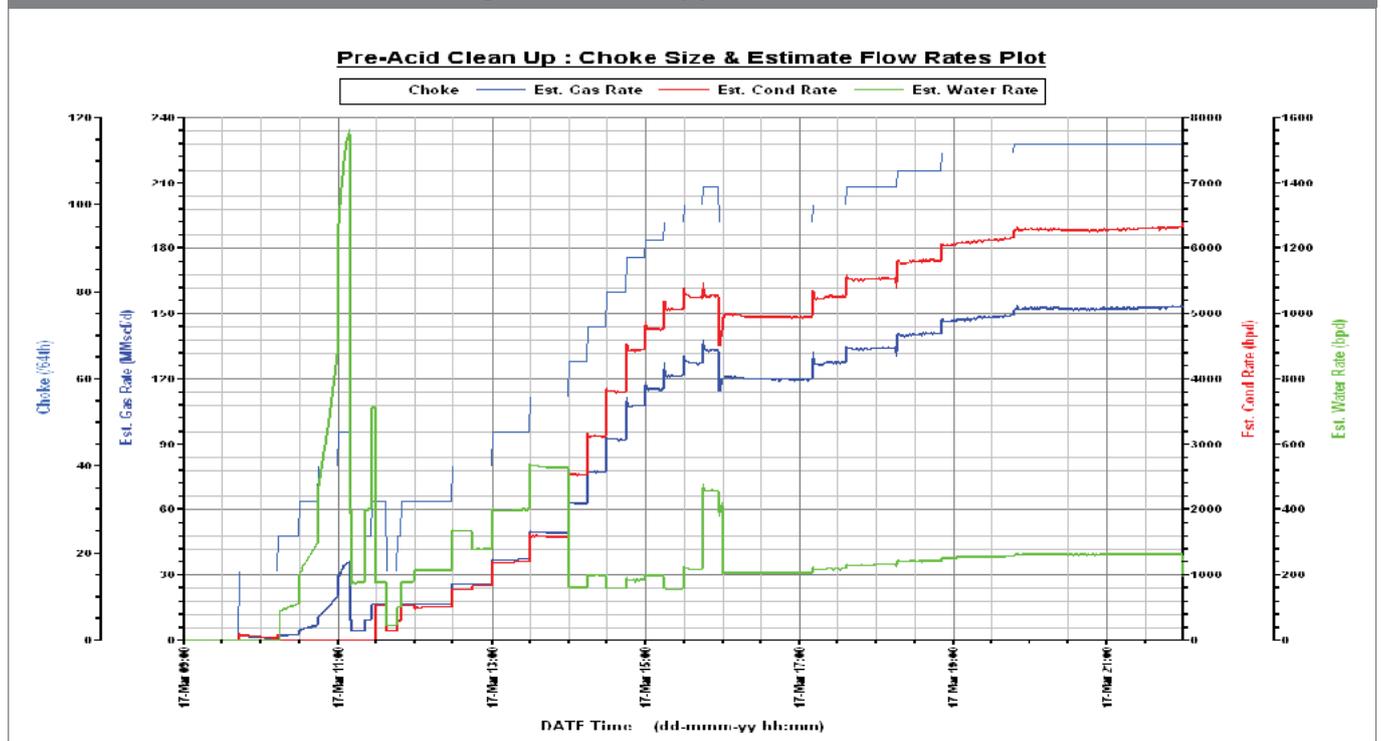


Low-solids formate brines used in combination with managed pressure drilling (MPD) delivered highly productive wells in a fractured carbonate reservoir without incurring excessive fluid losses while drilling. No acid stimulation was required.

Kanowit is a gas-condensate field located 200 kilometres offshore Sarawak in Malaysia with water depth of 78 metres (256 feet). The fractured carbonate reservoir has a temperature of 112°C (234°F) and pre-production pressure of 286 bar (4,146 psi). The reservoir peaks at 1,686 metres (5,531 feet) TVDSS and has a thickness of 264 metres (866 feet). Average reservoir permeability is 108 mD with original gas reserves estimated at 21 billion m³ (740 billion ft³). The gas contains 5% CO₂ and 32 ppm H₂S.

The Kanowit field development plan involved two wells drilled from 1,735 to 1,847 metres TVDDF, each with a 7" pre-drilled liner installed across the deviated (26–30 degrees) 100–200 metre openhole sections. Target gas production was 100 MMscfd from each well. With a high-pressure reservoir, fluids of equivalent mud weight greater than 1.80 g/cm³ (15.0 lb/gal) were required to maintain well control. Equally, the development plan required low-solids well construction fluids to minimise formation damage, ensure maximum gas production rates and restrict solids passing through gas processing facilities on production start-up.

Gas, condensate and water-flow rates during the initial clean-up phase of well SS-1



Well SS-1 was producing over 150,000 MMscfd of gas and more than 6,000 bbl/day of condensate within nine hours of opening.

MPD to minimise losses

Previous drilling experience in the area suggested there was a high probability of losing large volumes of fluid to the reservoir while drilling conventionally in overbalance with high-solids, high-ECD fluids. To avoid this issue, Petronas Carigali used 1.52 g/cm³ (12.7 lb/gal) statically and dynamically underbalanced formate drilling fluid in combination with MPD technology to control the level of overbalance through back pressure. The reservoir section of each well was successfully and safely drilled with potassium formate at 150 psi overbalance with a controlled average ROP of 15–17 metres/hour without significant fluid losses.

On reaching target depth, the potassium formate drilling fluid was displaced to kill weight 1.81 g/cm³ (15.1 lb/gal) low-solids formate brine tripping fluid before running 7" pre-drilled liners. The tripping fluid was then displaced to 1.81 g/cm³ (15.1 lb/gal) clear formate brine for the upper completion operations. Upper and lower completions were installed in an average of 40 hours and 29 hours respectively with minimal formate completion fluid losses per well. The formate filter cake cleaned up naturally without acidisation, using a rapid bean-up method that achieved full clean up within 11 hours. Low-solids loading of the formate fluids ensured that well-test separators were not damaged or blocked by back-produced solids during the cleanup phase.

Improved project economics

Multi-rate well-flow testing showed that both wells could produce at an absolute open-flow rate greater than 150 MMscfd, which is 50% higher than the original technical potential estimated in the field development plan. High-rate acidisation with 15% HCl and gel diverters in one of the development wells (SS-1) was unable to improve gas flow rates or PI, suggesting that formate fluids had already achieved highly conductive wells.

This first-ever deployment of an underbalanced formate brine system for drilling a carbonate reservoir in MPD mode reduced costs and improved safety by:

- Eliminating lost circulation and associated fluid losses
- Allowing use of lower-cost, lower-density brine for drilling
- Providing early kick and loss detection

The combination of formate brine and MPD technology improved project economics further by delivering highly productive wells that did not require acid stimulation.

Literature

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Glossary

bbl/day	Barrels per day
ECD	Equivalent circulating density
Ft ³	Cubic feet
g/cm ³	Gram per cubic centimetre
lb/gal	Pound per gallon (US)
m ³	Cubic metre
mD	Millidarcy
mmscfd	Million standard cubic feet per day
MPD	Managed pressure drilling
PI	Production index
ppm	Parts per million
psi	Pounds per square inch
ROP	Rate of penetration
TVDDF	True vertical depth drill floor
TVDSS	True vertical depth subsea