Using Autonomous ICDs to Maximize Oil Recovery from the North Sea Machar Field

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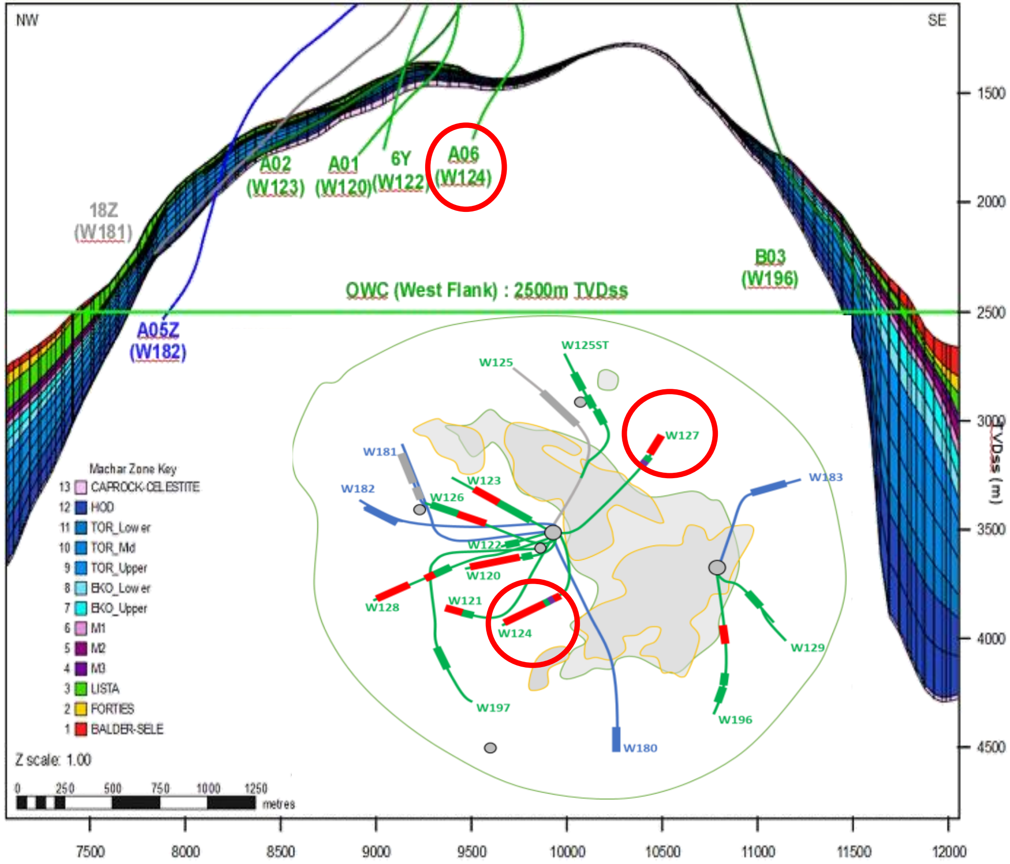
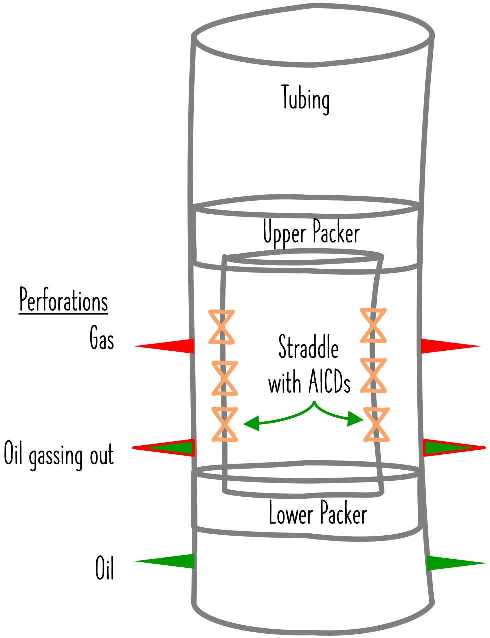
Machar field summary

- Producing under waterflood since 1998, tied back to ETAP CPF in the Central North Sea using 35km pipeline
- Steeply dipping, fractured Cretaceous chalk and Palaeocene sandstones draped over a high relief salt diapir
- Water injection stopped February 2018 to begin blowdown
- First blowdown of fractured chalk reservoir following waterflood within bp
- Focussing initially on oil recovery followed by gas production
- No direct global analogues
- With pressure depletion, gas is coming down-dip
- Two wells with AICD retrofits: W124 and W127

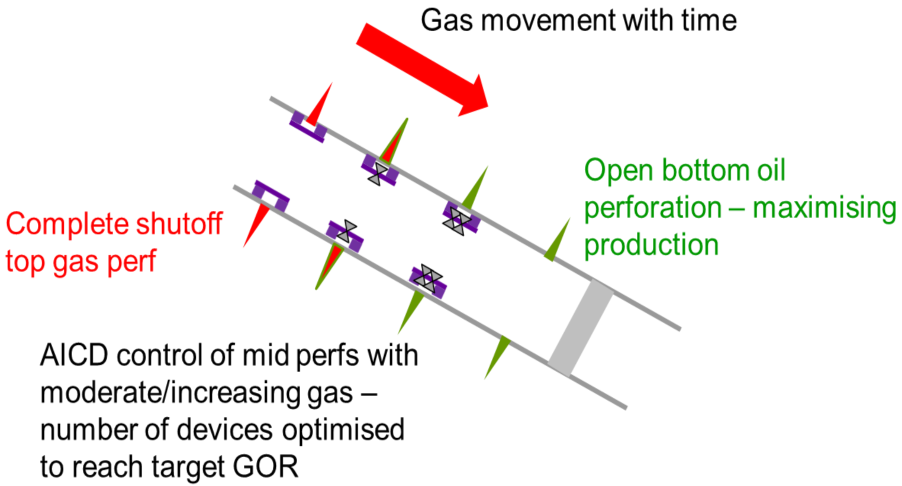


AICDs – Setting in the well



Machar W124 & W127 Summary

- W124 first intervention for managing Machar blowdown
- W124 key crestal well – early drop in watercut but rapid gas increase – unmanageable within pipeline constraints
- August 2020 successfully set AICD straddles with gas control matching predicted performance
- W127 subsequent 2021 application with further success in GSO
- New technology for a UK North Sea subsea intervention – AICDs



Principle: Autonomous ICD levitating disk

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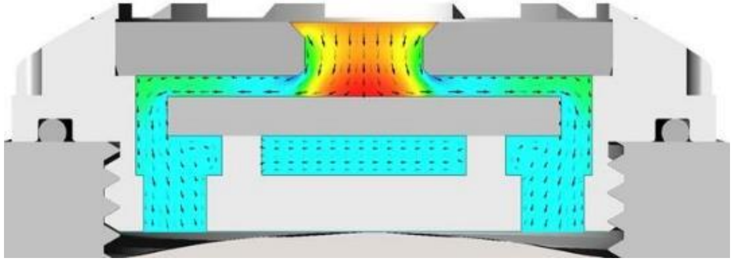
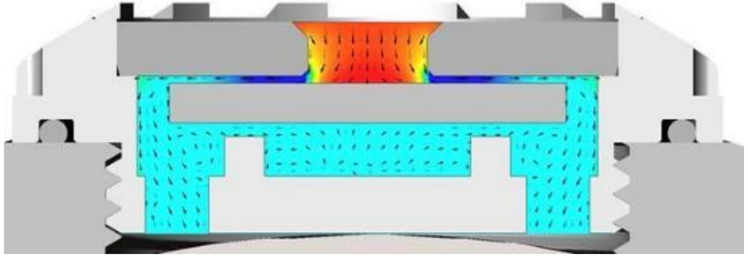
CFD Analysis – pressure plot



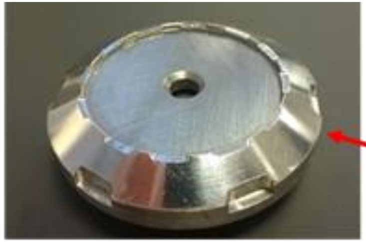
OIL

Disc lowers, restricts at inlet



GAS

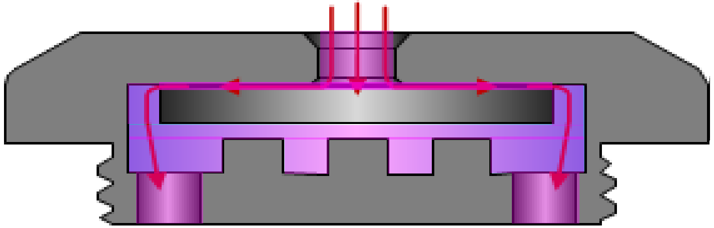
Disc levitates, restricts between disc



Floating disc determines production choke effect – responds to density and viscosity contrast

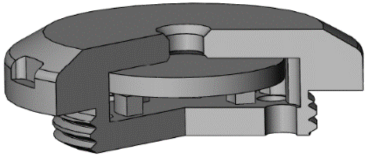
- More than 210 wells with Tendeka FloSure AICD
- More than 35,000 AICD valves installed
- 27 operators across the globe

Principle: Autonomous ICD levitating disk



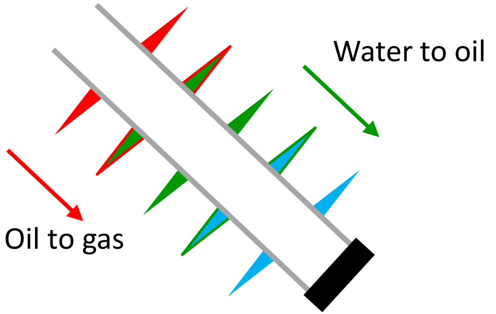
Three forces are acting on the disc

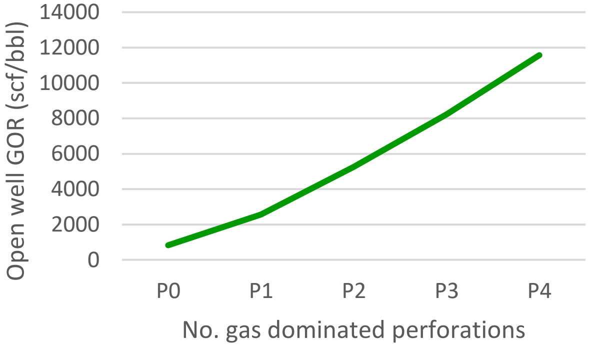
- ↓ F_{mom} = Force due to momentum
- ↑ F_{lift} = Force due to hydraulic lift
- ↓ F_{drag} = Force due to viscous drag

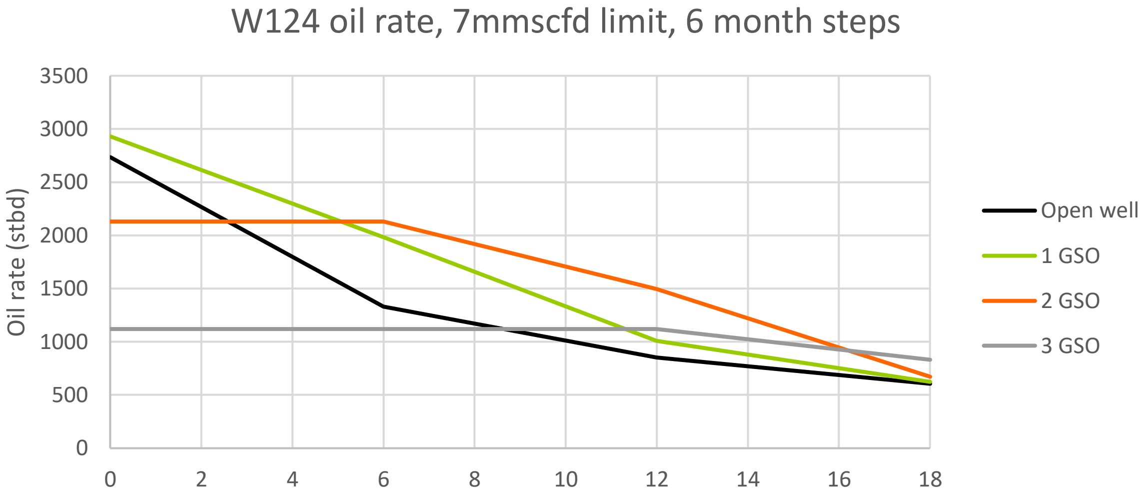


Intervention planning – W124 gas control challenge

- W124: increasing GOR but declining watercut
- Subsea pipeline stability gas constraint – unable to open up well to full oil potential
- Significant uncertainty in rate of gas progression – is there a single intervention solution robust to all scenarios without shutting off oil?

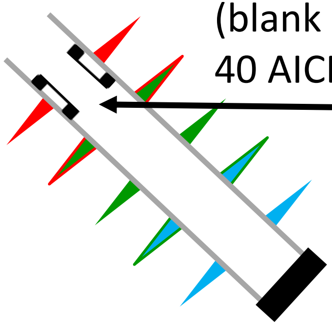


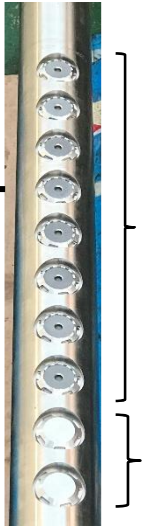




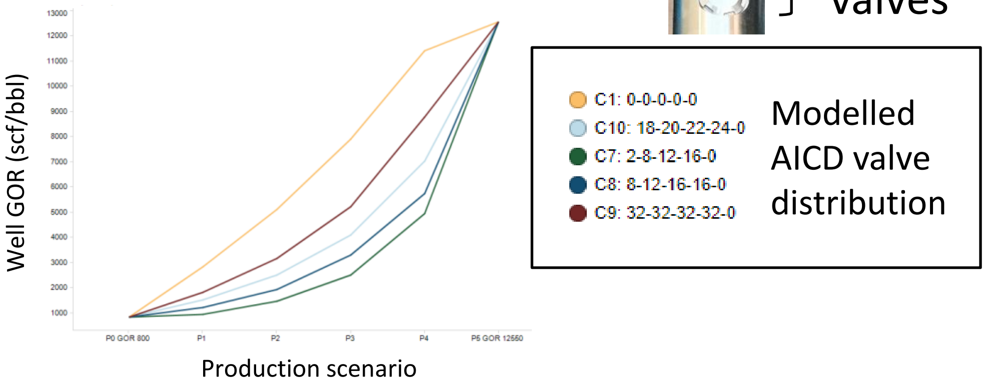
AICD modelling process

- Initial collaboration with Tendeka to test concept
  - Potential AICD setups
  - Test against future increasing GOR scenarios
  - Value case for AICDs
- Developed internal simplified well/AICD model for rapid scenario testing and support live optimisation
  - Multi-layer well model
  - Match well performance to a range of perforation production scenarios
  - AICD equation implemented – vary no. valves per perforation



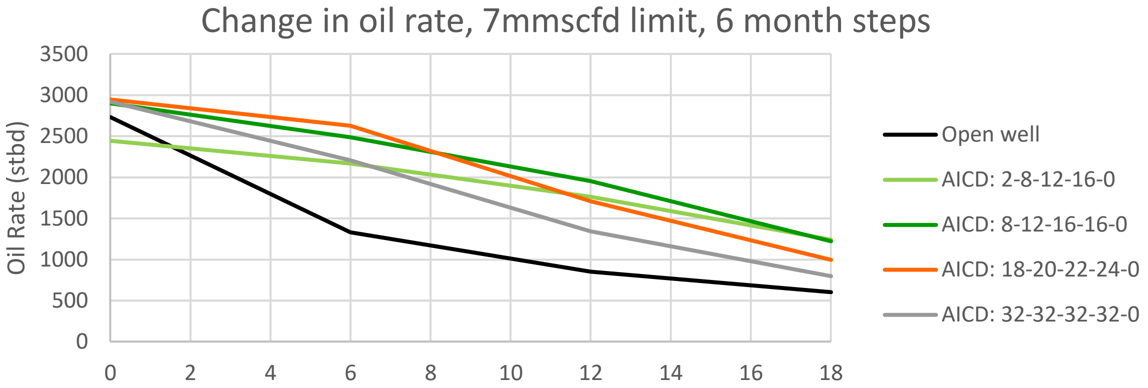


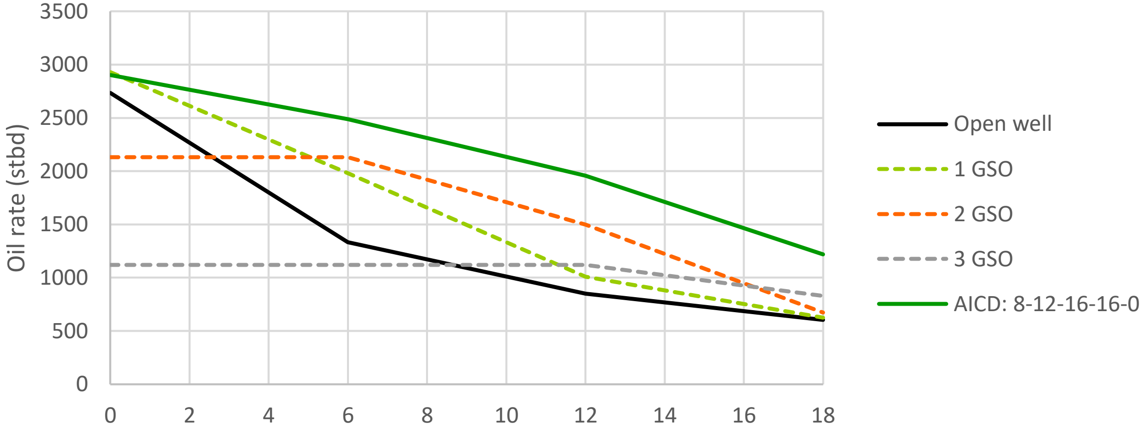
GOR impact of different AICD setups



Pre–intervention AICD model results and value

- Comparison of shutoff and AICD setups against range of future well performance
- Test flexibility of intervention against different scenarios
- Define potential no. AICD valves required for straddle design and planning
- Ensure well productivity not overly constrained: value from being able to increase well drawdown





W124 AICD setup optimisation

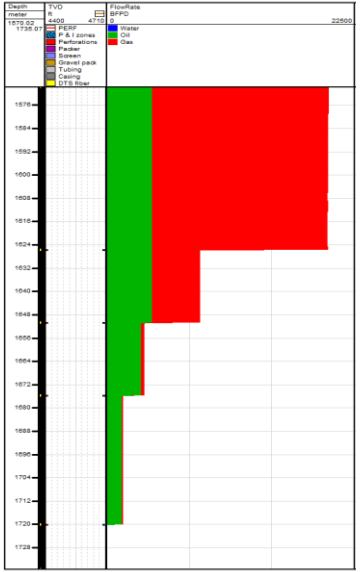
Production log data perfation match

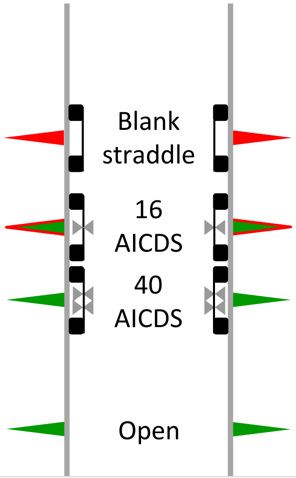
Check total production vs. latest steady state well test data

Optimise shutoff zones/AICD numbers testing future gas progression

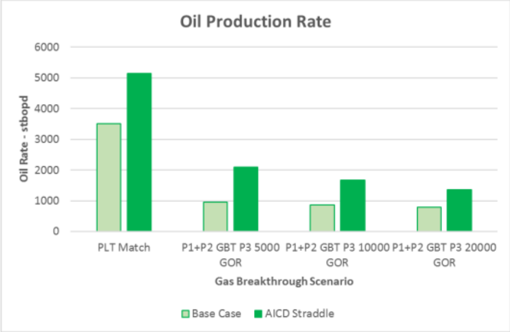
Run optimal scenarios with Tendeka AICD model

Adjust AICD setup offshore and deploy in straddles

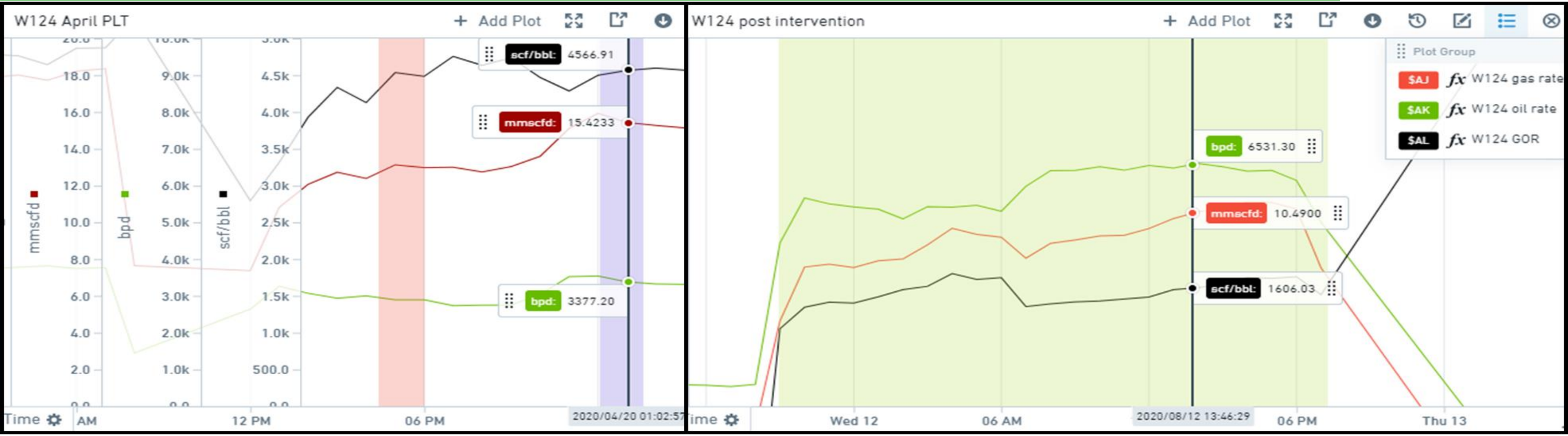




	Rate 1 - 13.1mmscfd and 2.9mbd (4500scf/bbl)			Rate 2 - 15.9mmscfd and 3.5mbd (4500scf/bbl)		
	Surface Conditions			Surface Conditions		
Perf No.	Gas	Oil rate	GOR	Gas	Oil rate	GOR
	mmscfd	stbd	scf/bbl	mmscfd	stbd	scf/bbl
1	8.3	20	45800	9.4	50	193200
2	3.3	660	5000	4.7	570	8300
3	0.9	1250	700	1.2	1730	700
4	0.6	1010	600	0.6	1130	600



W124 results – first restart vs previous PLT



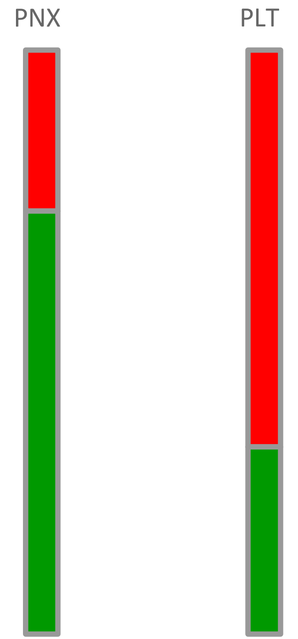
- Similar standalone max. rate tests – W124 shut-in before intervention
- Immediate benefit to Machar: ~3mbd
- Gas control matched model results: ~1600scf/bbl
- A reduction in gas-oil ratio of 60% keeps the field within facility production constraints and retains reservoir energy for oil production.

W127 Results and Surveillance Insights

- Completed 2021
- Working DHG simplified the modelling
- Gas shut-off with 1 straddle using 8 AICDs across top perforation in well – other two perfs left open
- Immediate field rate benefit of approx. 1.6mboed declining to 0.5mboed after 12months

- Blowdown so far:
  - Fracture network dominating behaviour – rapid well performance changes
  - Recent saturation log data supporting understanding - gas production from perforations below matrix GOC, oil production from perforations with high matrix Sw

Fluid contact in W127 interpreted from downhole surveillance



Operational challenge – “even better if”

- Differential pressure across AICDs limited to 600psi
- Potential for reduced gas control at higher differential pressures
- Influences initial AICD setup and number required per zone
- W124 challenge due to loss of downhole gauge – more conservative operational limits required
- A downhole gauge or a robust well model can be used in higher drawdown environments to give confidence of sustainable production with AICDs and increase operating window

Summary

- AICDs have resulted in one intervention per well as opposed to a phased intervention strategy within subsea wells to reduce GOR and manage gas offtake
- 2020 application the first retrofit AICD installation in the UK North Sea
- Upfront and real-time modelling alongside production logs optimised the number of AICDs set
- Operating AICDs within their limits results in sustainable production gains
- Machar blowdown prize is underpinned by this technology and supports the strategy enabling maximum economic recovery of the field

Questions?

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