Hydraulic fracture stimulation on Clair Ridge well with CT fibre optic technology

James Paterson, bp
Aigerim Balgozhenova, SLB

wells

Presentation contents

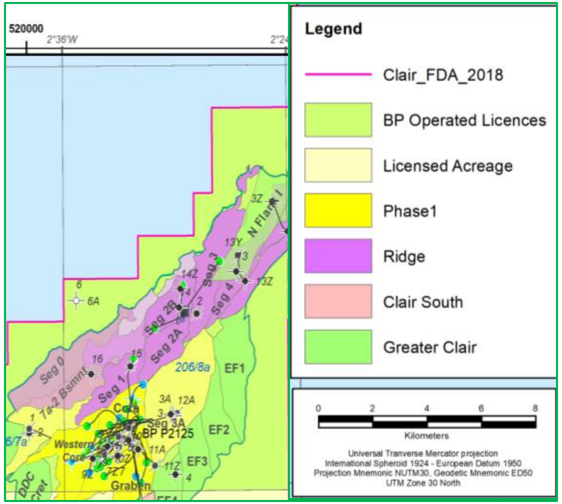
- Field background
- Well summary
- Hydraulic fracturing overview
- CT challenges and solutions
- Real-time CT technology
- Sleeve shifting operations
- SIMOPs challenges
- Results
- Conclusions and next steps
- Acknowledgements

Clair Ridge platform at Clair Field

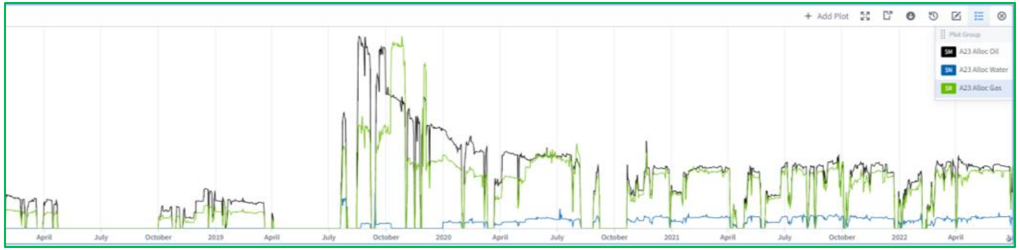
Clair Field background

- Largest UK Offshore oilfield (>6 billion BOE)
- Discovered in 1977 but not developed until 2005
- Clair Phase 1 (2005) and Clair Ridge (2018) platforms
- Permeabilities 3–25 md, porosity 12–15% (Units V and VI)
- Horizontal wells targeting natural fractures
- Value of hydraulic fracturing for Clair: A23 on Phase 1 was stimulated in 2019 – delivering threefold production increase

Location of Clair oilfield



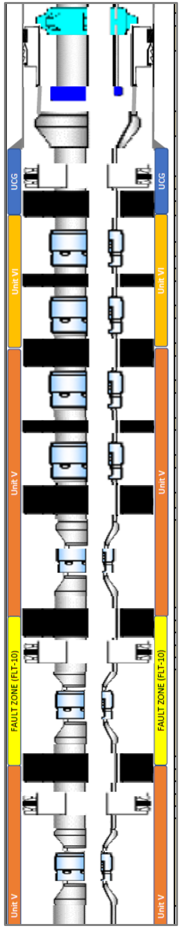
Clair Field area – Phase 1 and Ridge



A23 production history

Well summary and completion design

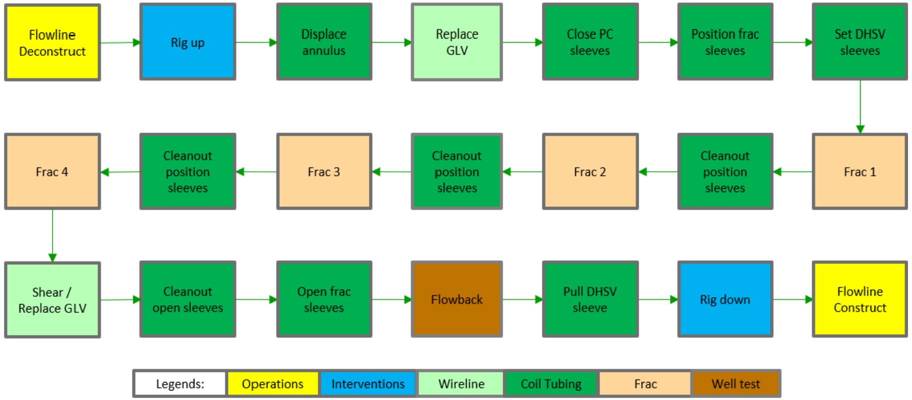
- Horizontal multizone producer
- 8 ½-in. openhole reservoir section
- Mechanical sliding sleeves and swellable packers
- Four fracture zones (total of seven zones)
- Upper and lower completion—5.5-in., 13Cr 80ksi
- Tubing rock anchors to support against axial load under fracturing loads and to assist with packer integrity after fracturing
- Well B09: first to be fully designed for hydraulic fracturing on Clair Ridge
- The well did not target natural fractures, instead drilling through largely matrix reservoir
- Completed in January 2021 in Unit V and Unit VI reservoir



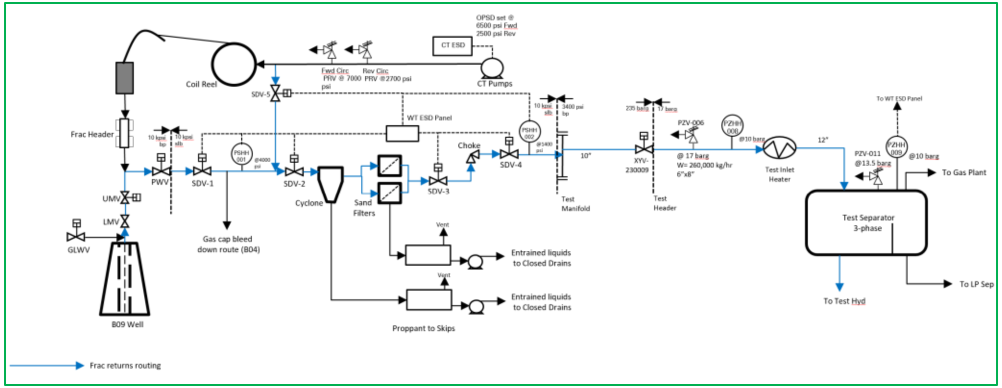
B09 completion schematic

Well intervention overview

- Multiple services and interfaces are required to deliver a complex activity offshore:
  - Coiled tubing, wireline, cleanup package, stimulation vessel
  - Drilling and completion (rig operations)
  - Production operations
- Intervention sequence:
  - Replace gas lift valve (GLV) with dummy (wireline)
  - Close all sleeves (CT) and pressure test
  - Open frac sleeve (CT)
  - Stimulate zone
  - Reverse circulation cleanout proppant (CT)
  - Close frac sleeve and open upper sleeve (CT)
  - Repeat for all zones
  - Shear open GLV
  - Cleanout well to total depth (CT)
  - Flowback



Planned well intervention sequence



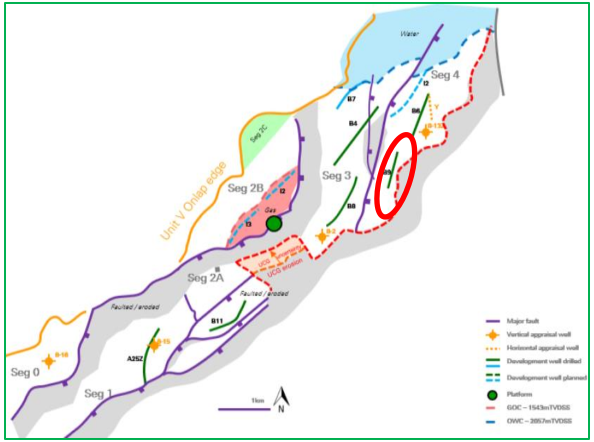
Coiled tubing and cleanup package setup

Hydraulic fracturing design

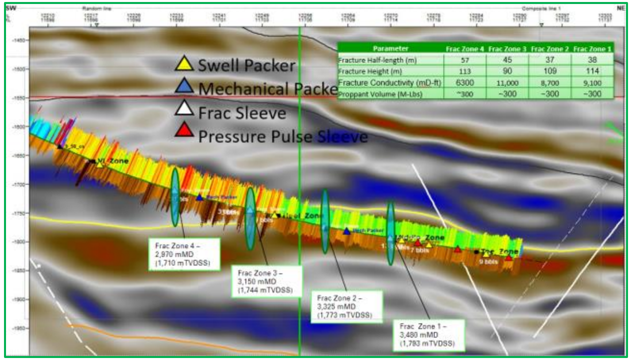
- 20/40 and 16/20 light-weight proppant
- Resin-coated design for low Clair temperatures
- 150,000–300,000 lbm of proppant per stage
- Designed to be pumped at max 30 bbl/min; 8 PPA maximum proppant concentration
- Tip screenout (TSO) fracture design
- Proppant under-displaced in the well by up to 5 bbl to ensure good wellbore connectivity at the fracture opening
- Under-displaced fractures require CT cleanout after each frac stage
  - Bottomhole pressure management during CT cleanout critical to avoid fracture re-opening!

Parameter	Recommendation
Fracture height	Maximized vertical cover of Unit V and Unit VI
Fracture half-length, m	50
Fracture conductivity, md-ft	5,000 - 10,000
Proppant volume, lbm	150,000 - 300,000
Proppant type	20/40 with 16/20 lightweight resin-coated proppant

B09 fracture design recommendation summary



Clair Ridge Unit V wells



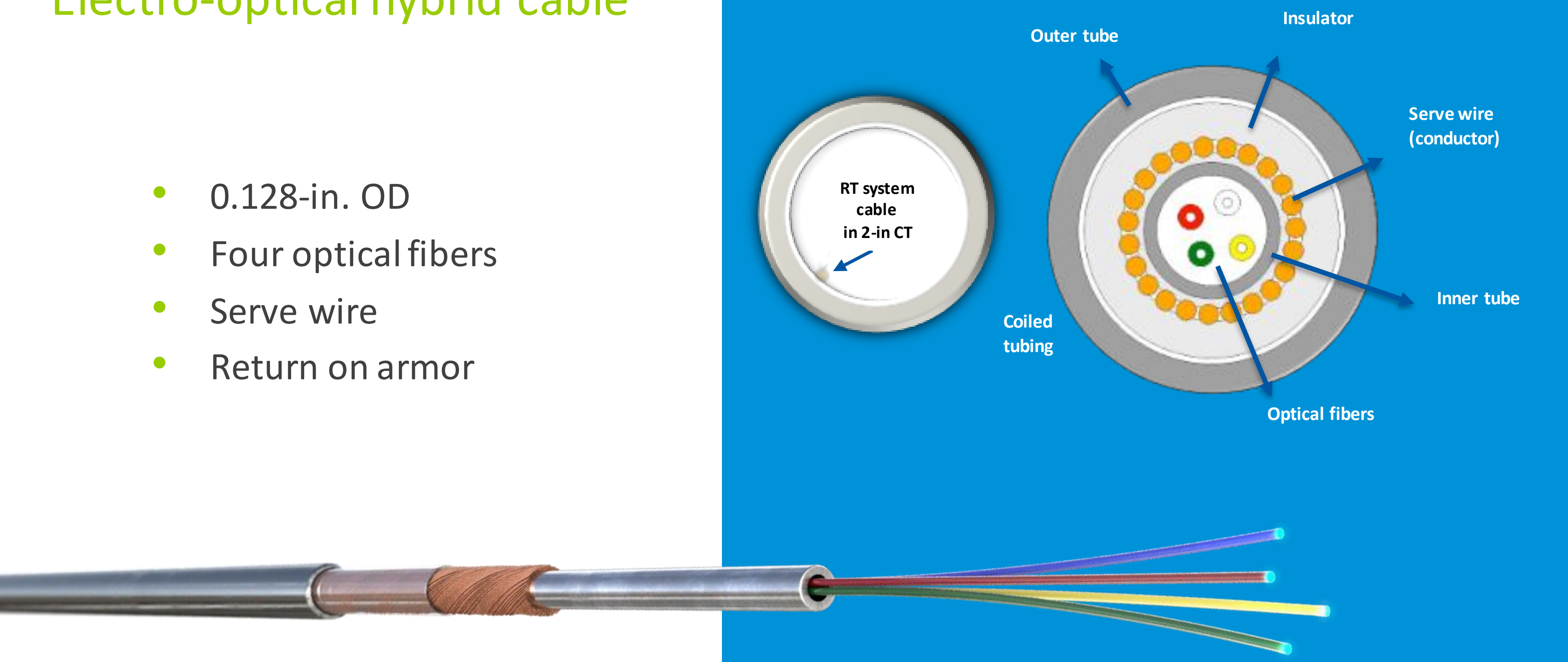
Planned fracture placement

Coiled tubing challenges and solutions

Challenges	Solutions
Narrow operating window	DH sensors
Operating time optimization	Eliminating batteries
Decision time efficiency	Real-time data transmission for onshore support
DH load management	DH load sensors indications
Understanding DH conditions	Interpretation of multiple sensors output

Electro-optical hybrid cable

- 0.128-in. OD
- Four optical fibers
- Serve wire
- Return on armor



RT tool assembly and applications

RT MHA assembly and CT head power module

Pressure and temperature module

Depth control module

Load module

RT system logging adapter

Wireline production logging tools

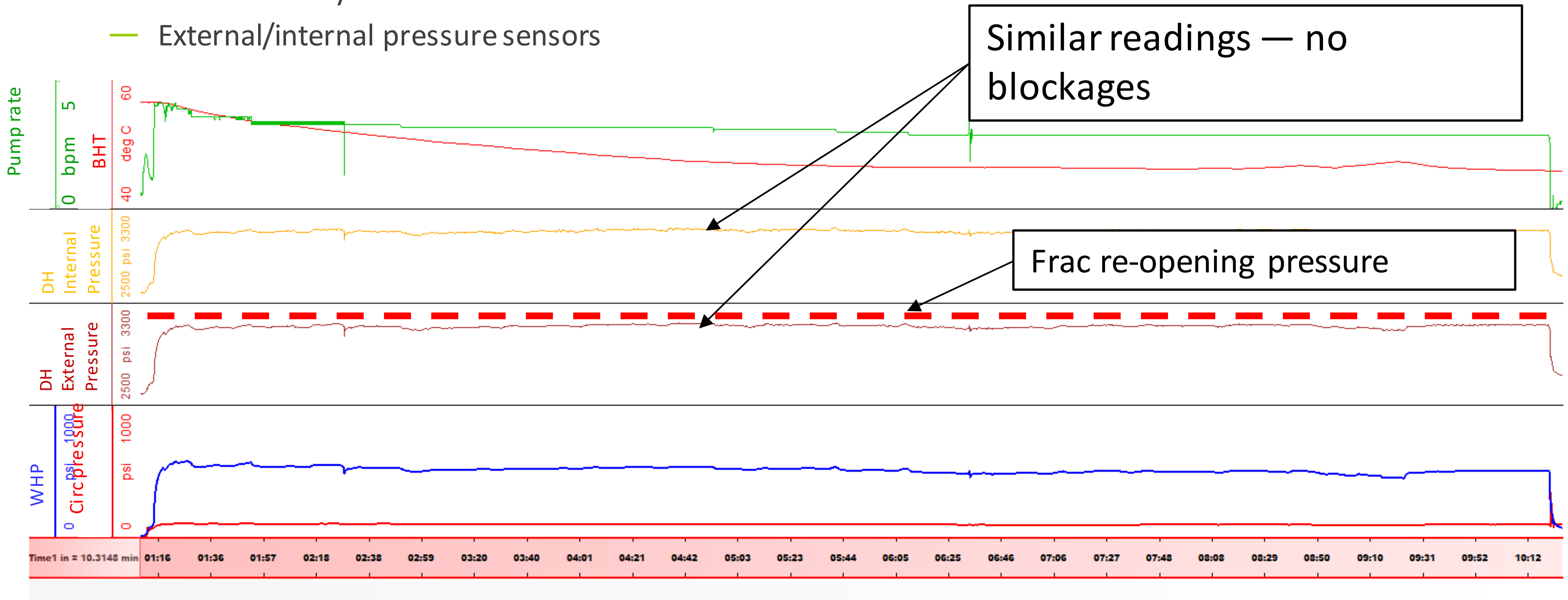
- Contingency - WL perforating BHA
- Contingency – EST Retrievable bridge plug setting BHA

CT application tools

- Reverse BHA
- Sleeve shifting BHA
- High-pressure jetting BHA
- Protection sleeve setting BHA

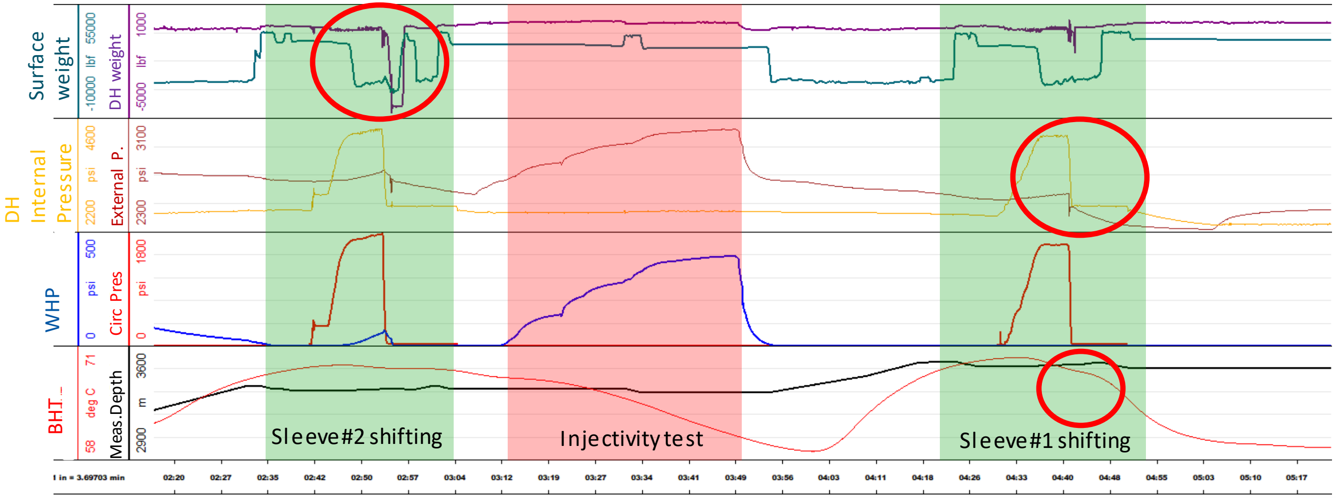
Utilization of sensor data — reverse cleanout

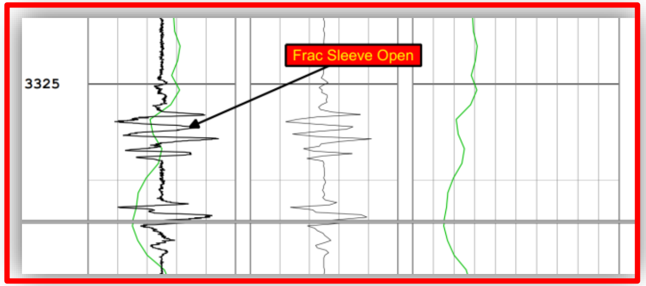
- Importance of downhole pressure monitoring:
  - Low bottomhole pressure and frac re-opening pressure
- Early detection of CT blockages:
  - Ensured timely identification and resolution
  - External/internal pressure sensors

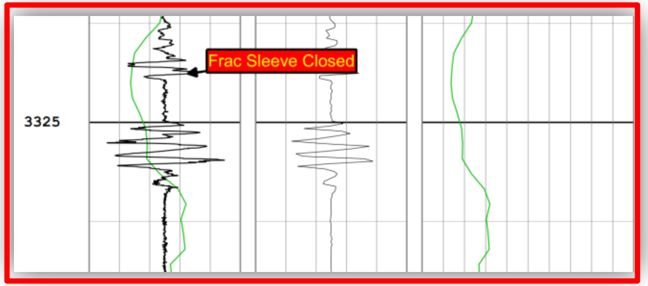


Utilization of sensor data — sleeve shifting

- Leak detection with distributed temperature survey
- Verification of sleeve re-positioning by:
  - Downhole tension/ compression
  - CCL
  - CT pressure external/internal and temperature

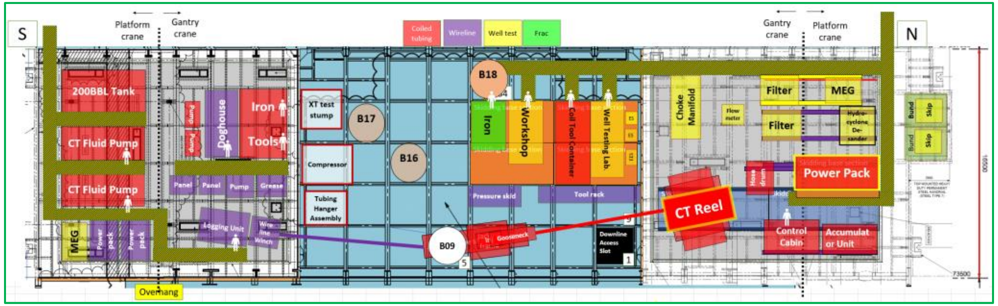




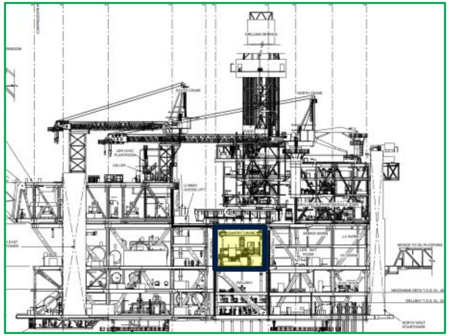


SIMOPs challenges

- Requirement for multiple equipment packages in single operation
- Intervention constrained to production deck
  - Limited deck area
  - Available height
  - Weight load limitations



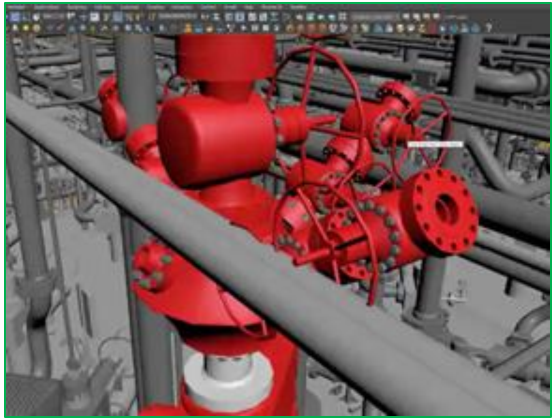
Positioning plan — “deck chess”



Highlighted: Intervention deck at Clair Ridge

Multiple equipment packages on deck for B09

Leveraging technology for success



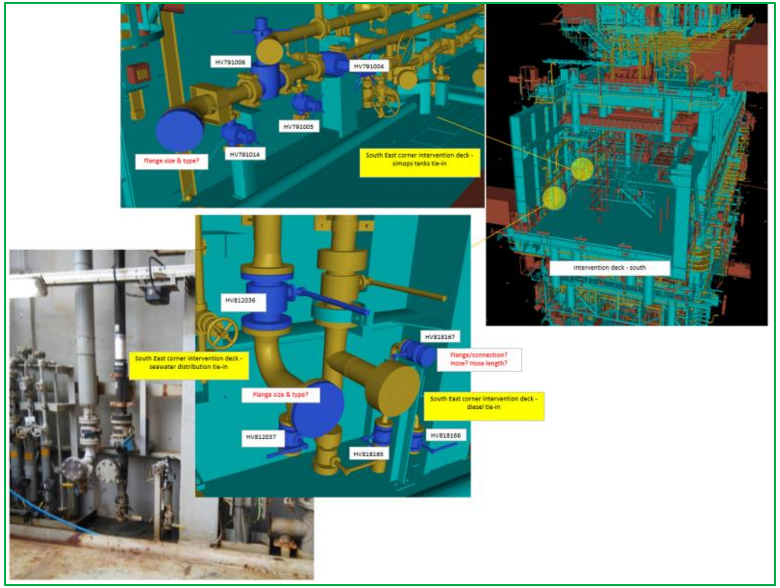
3D model indicated PCE frac head clash

Use of 3D model to identify clash of CT injector and jacking frame

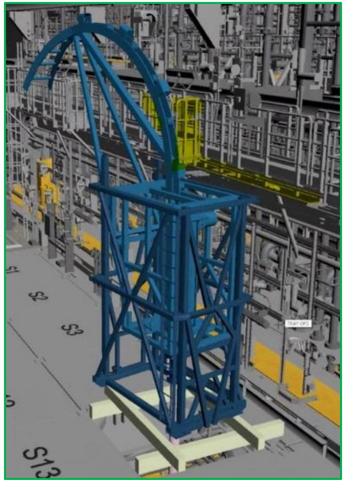
- 3D visual tools (platform digital twin)
  - Clash 1: coil injector jacking frame and injector with the walkway above
  - Clash 2: platform pipework and the frac head

- CT fibre-optic cable for live data stream
  - onshore monitoring, interpretation, and real-time support
- Shearable gas lift valve (GLV)
  - Positive pressure in the annulus (dummy valve) during fracturing
  - Conventional orifice GLV after fracturing by shear-out

Digital twin in intervention planning



Clair Ridge digital twin — utilities identification



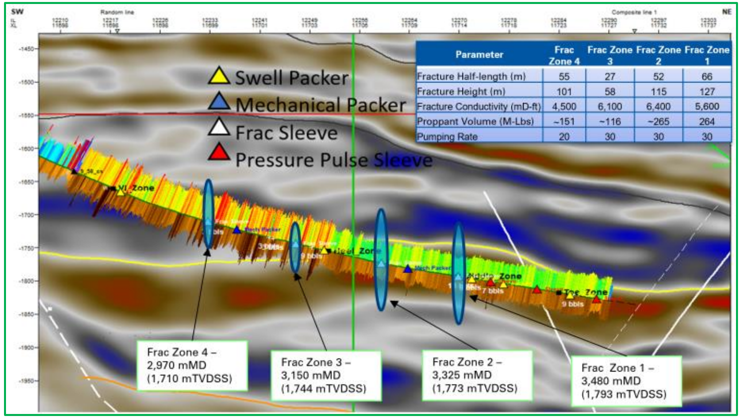
3D digital twin model

Deck layout yard trial

Equipment offshore

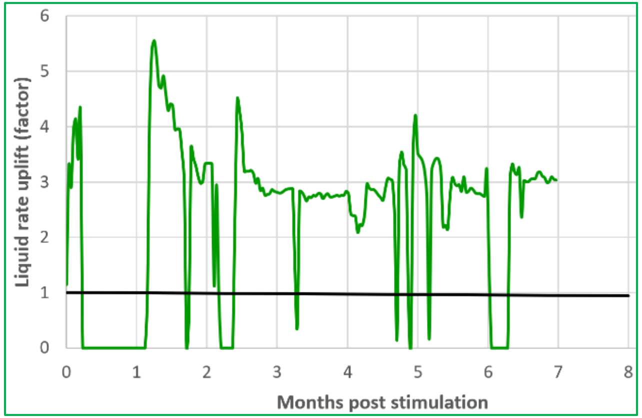
- Digital twin — develop layouts virtually and test in yard prior to mobilisation
- Visualisation of worksite — Identify potential hazards and clashes, minimise HSE risks and NPT
- Input to site survey and HAZID/HAZOP processes — understand how work actually happens

Results



Parameter	Frac Zone 4	Frac Zone 3	Frac Zone 2	Frac Zone 1
Fracture Half-length (m)	55	27	52	66
Fracture Height (m)	101	58	115	127
Fracture Conductivity (mD-ft)	4,500	6,100	6,400	5,600
Proppant Volume (M-Lbs)	~151	~116	~265	264
Pumping Rate	20	30	30	30

B09 actual fractures placement



Production uplift, normalised to pre-fracturing rate (black)

- Four fractures placed as designed: two in Unit V and two in Unit VI
- Zones 1, 2, and 4 achieved design goals and fracture dimensions
- Zone 3 resulted in a premature screenout

- Instantaneous production increase by factor of 5.5
- Stabilised production increase
- Gas lift removal post fracturing — well flows unassisted

Conclusion: learnings and next steps

- Demonstrated capability of delivering complex fracturing intervention SIMOPs with an ongoing drilling programme
- Hydraulic fracturing can deliver significant value by improving well productivity on Clair Ridge
- Complex SIMOPs requires extensive planning and communication between teams
- Leveraging available technology to de-risk and simplify operations
  - 3D tools / digital twin
  - Real-time data stream and powered CT
  - Shearable gas lift valves
- Future offline stimulations will aim to improve efficiency using a single trip multi-frac (STMF) technique
- Expand the capability of CT intervention (e.g., GLV c/o on powered CT)
- Build on 3D visualisation by developing a full 3D model of entire spread

For more information refer to *SPE-215632-MS. Case Study: First Multistage Fracturing SIMOPS with Concurrent Drilling Operations in Clair Ridge Field, North Sea*

Acknowledgements

- Presentation Partner:

The presenters would like to thank bp Exploration Operating Company Ltd and the other Clair Field owners for their kind permission to share this case study.

wells

Any questions?