Learning from Experience: Completing a Subsea Dual ESP Well, second time round.

Solan Field, West of Shetland

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Run Down

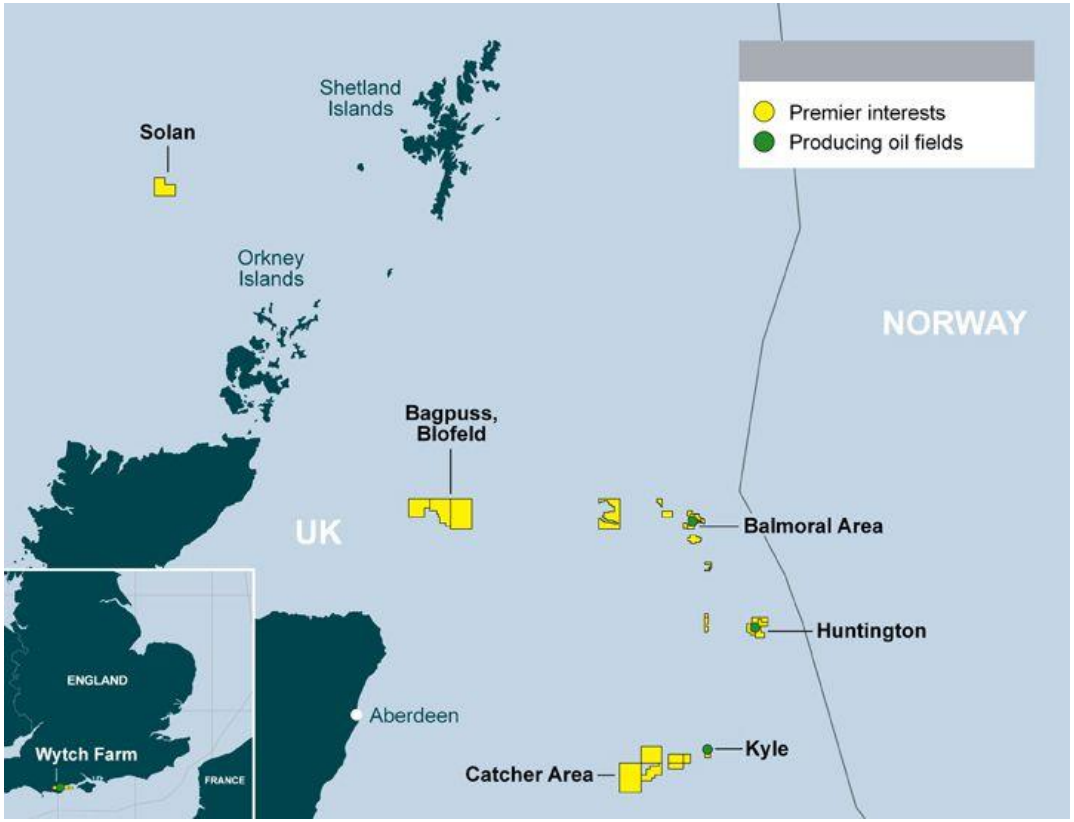
1. Background
2. ESP Life Cycle
3. Historical wells experiences - P1 and P2
4. New Well planning - P3
5. P3 Execution
6. P3 Learnings
7. Conclusions

Harbour Energy

- This project was completed under Premier Oil, installation concluded in July 2020
- Harbour Energy plc completed merger with Premier Oil (and Chrysaor) in March 2021

Solan Field

Solan lies in Block 205/26a of the UK continental shelf. It is 96 kilometres North West of the Orkney Islands and 135 kilometres 135 kilometres west of Shetland. The Solan field lies in a water depth of 135m.



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Solan Field

Solan comprises three producing wells and two injector wells tied back to a normally unmanned conventional steel platform. Oil is produced into a 300,000-barrel subsea storage tank and offloaded via shuttle tanker. First oil was achieved from Solan in April 2016.

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Transocean Leader

The Transocean Leader is a harsh-environment Semi-Submersible and was used for the campaign. It's drilling performance was excellent. It had the correct subsea capabilities. The rig had ESP running and handling experience.

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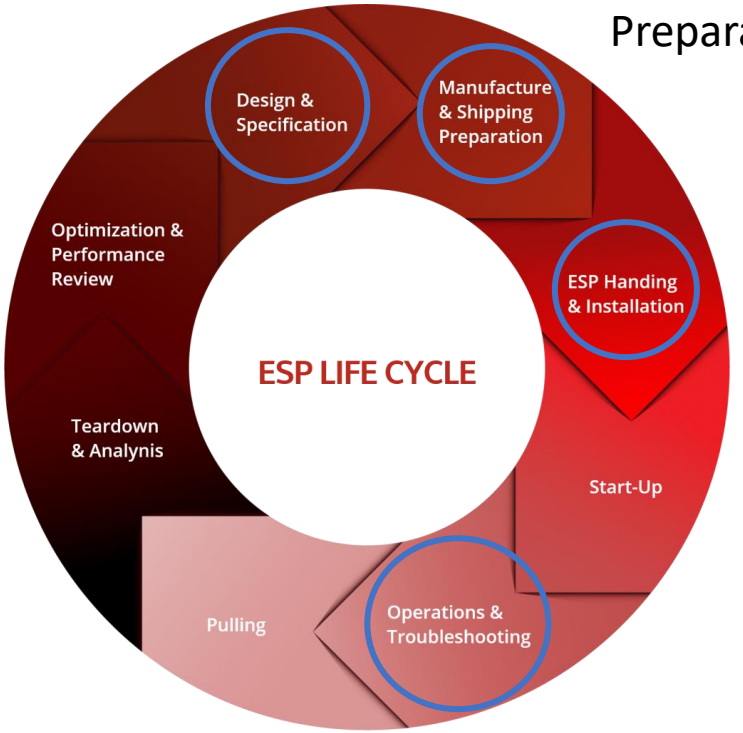
ESP Life Cycle

Applying learnings from P1 and P2 to define specification of P3



Preparation of equipment for P3

Install on P3

Learnings from P1 and P2
Learnings from P3 stack up

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P1 and P2 Experiences

- Two Dual Y-Tool ESP installations occurred in 2016
- Ended up running a single ESP in P1 due to issues

Problems:

- Major slack in MLE Cables (2 ft)
- Discharge Pressure Line too short for ESP assembly
- Systems were out of alignment during install
- Issues with Pump Sub

P1 and P2 Experiences

- The ESP wouldn’t pass through the GE HXT (Helix)
  - 11 days spent trying
  - Testing Y-Tool on drill pipe, it rotated 60° through the Helix
- Detaching Pump Support Block Spear
- ESP Bypass Clamps failed
  - Clamp sheared and was riding against Y-Tool

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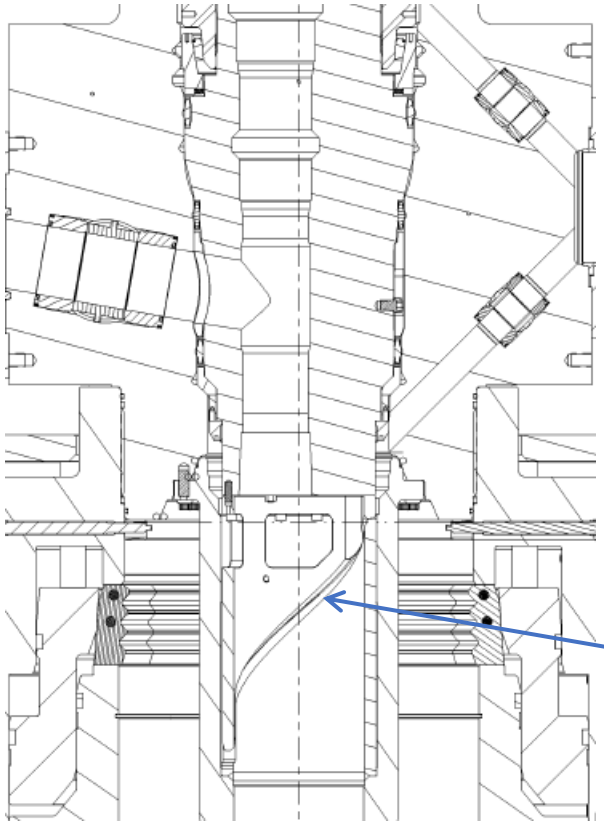
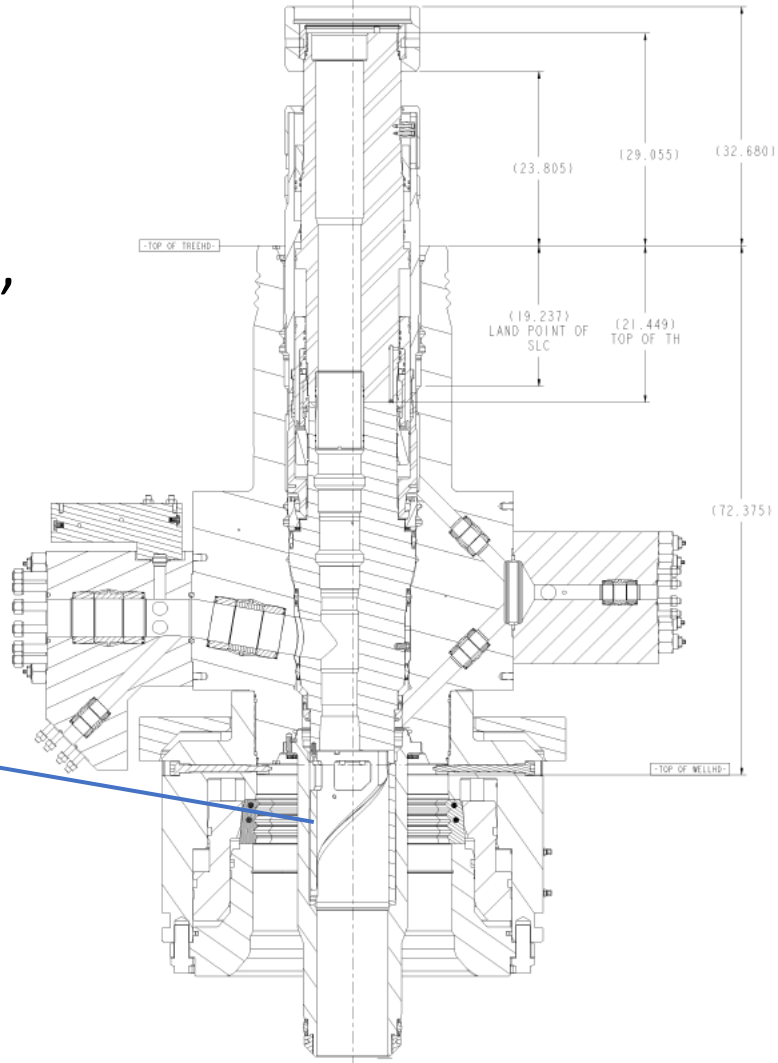
P1 and P2 Experiences



Helix profile
Tubing Hanger orientation
9.760” ID with a casing ID of 9.66”



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Suspected Causes

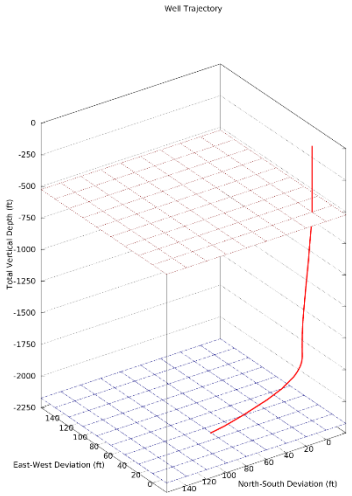
- Was the ESP too rigid for the casing?
  - Not enough flex to make it through the well profile
- Was the Bypass Clamp design optimal?
  - Bolts shearing
  - Bolts backing out
  - Large OD
- Was the MLE too heavy to manipulate?
  - Too heavy to pull tension on by hand when RIH
  - Too difficult to move when installing Bypass Clamps

Suspected Causes

- The systems being out of alignment?
  - Did this make the ESP oversized?
- Well Geometry optimal?
  - There was a Dog Leg in the profile
- Did the lower pump being in the riser for 18 hours contribute to issues?
  - Did the waves hitting the riser cause vibrations which backed out the clamp bolts?

P3 Plan

- It was a new drill well designed for an ESP
  - 1200ft tangent for ESP
  - DLS very low
  - Low inclination



- ESP needed to have:
  - high, variable rate
  - be capable of dealing with fine sands, H2S and CO2
  - Cable that was manageable

- Automatic / controlled Bleed off of Annulus

P3 Plan

- The ESP completion design had to be optimised
  - Distance between ESPs increased
  - Y-Tool designs minimal in size
  - Bypass clamp had to be more robust
  - MLE had to be more manageable
- ESP Quality had to be ensured
- Assurance was required for passing through the Helix
- Summer installation – best option for weather

P3 Plan

- Premier Oil contracted the services of Artificial Lift Solutions
- The ESP contract was awarded to Baker Hughes
  - Multiple services award
- Engenya were contracted for Design Analysis
- A stack up trial was planned

Quality Plan

- Collaboration was required in creating a robust Quality Control Plan that included sub suppliers

- The ESP quality plan included:
  - Full ESP parts and build inspection
  - SIT performed at factory
  - Full parts and build inspection at sub suppliers
  - Full FAT of Auto Y-Tools

- Additional qualification testing of new bypass clamp design

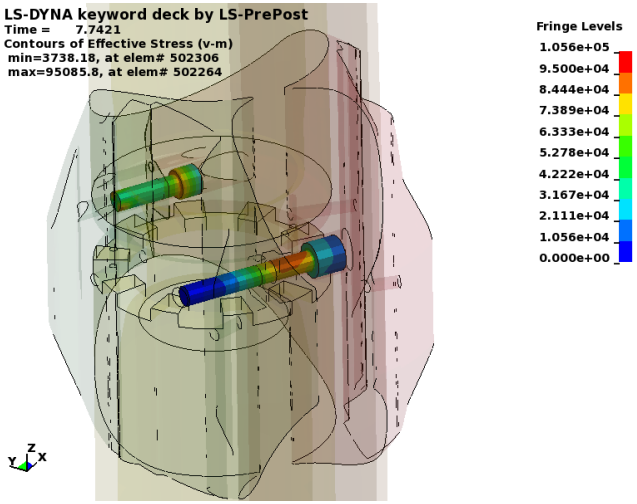
Bypass Clamp Design

- The Bypass Clamp redesign was a high priority due to issues faced previously
- RMSpumptools created a new design
- Robust two bolt clamp was created – no hinge.
- Reduced OD (9.563” to 9.504”)
- Nord-Lock Washers

- Ran Qualification testing
  - Shock Loading
  - Vibration Testing

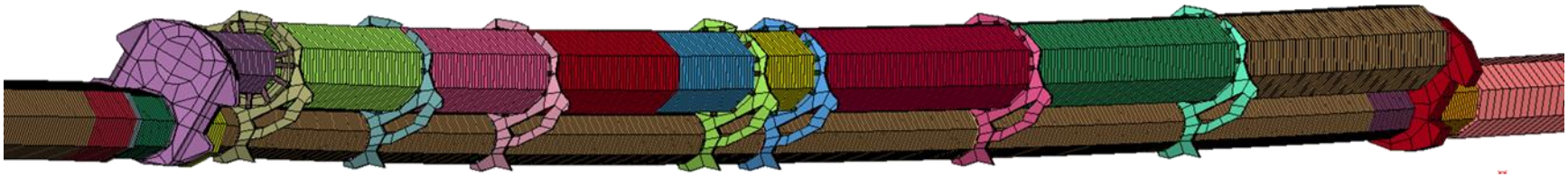
Bypass Clamp Design

- Engenya Design Analysis was run



Design Analysis

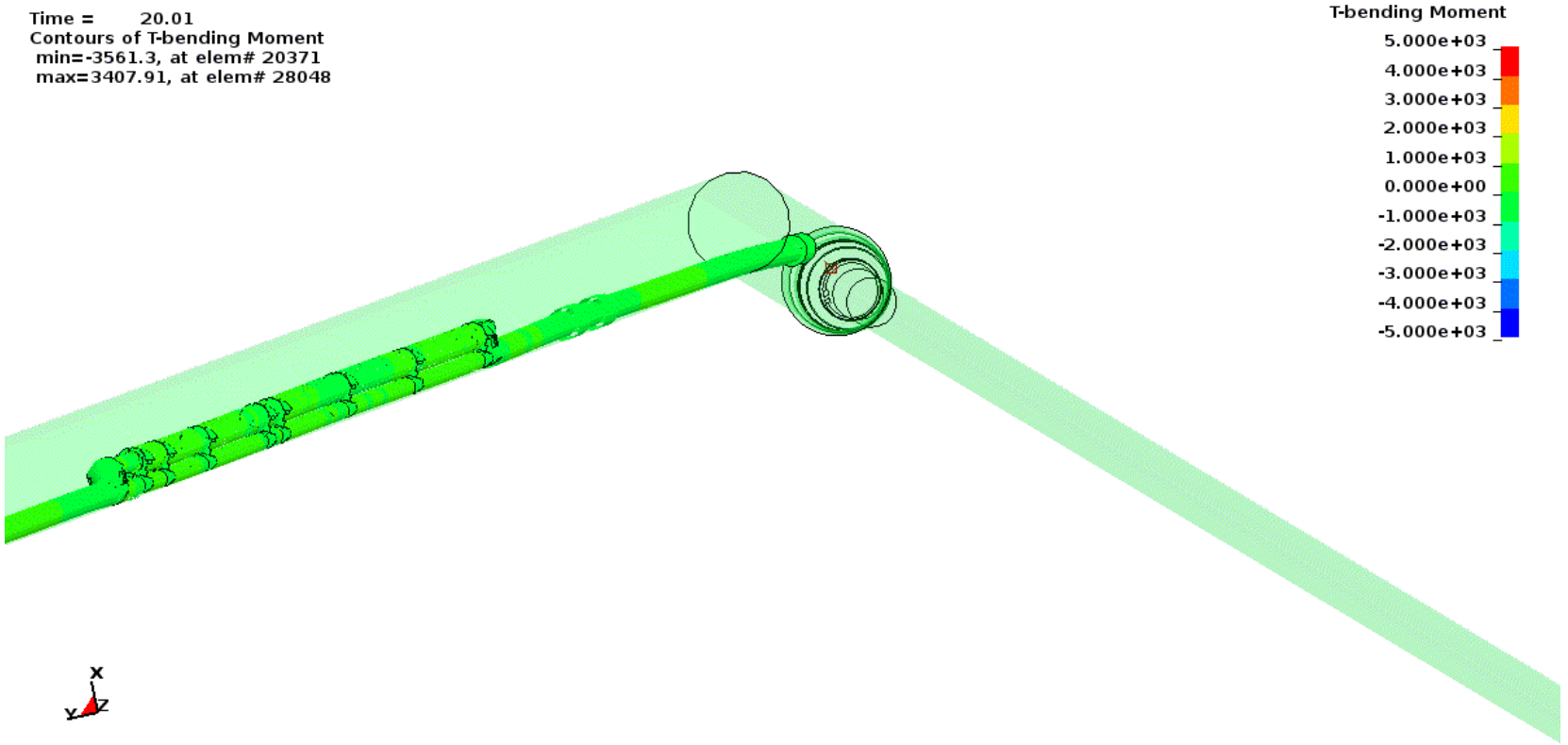
- Engenya created a full model and conducted FEA of the system at all stages of installation



- Note: Full analysis was done on P1 as hindsight

Design Analysis

- Please note, this is a generic ESP assembly – not manufacturer specific - to demonstrate the movement.



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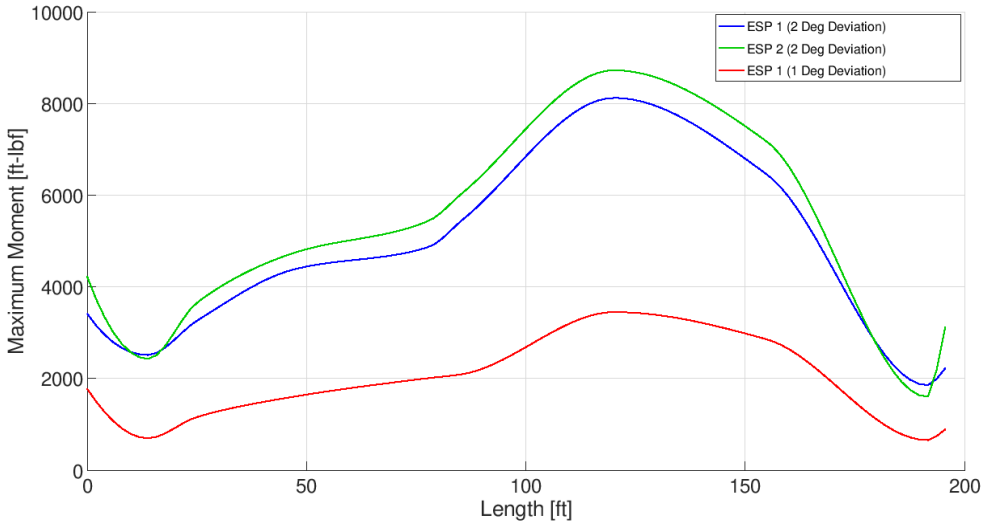
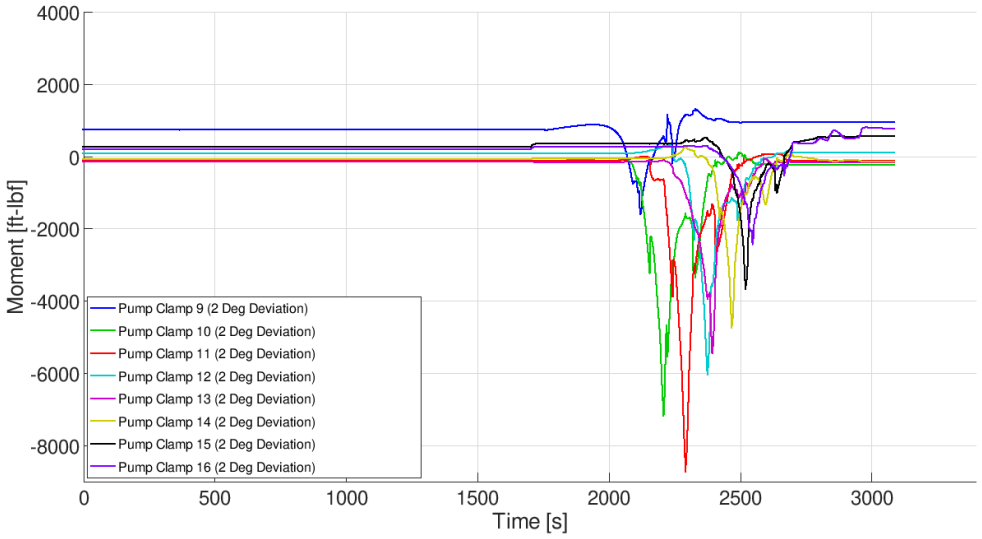
Design Analysis

- Maximum Moment v ESP Length



- Moment on ESP Clamps



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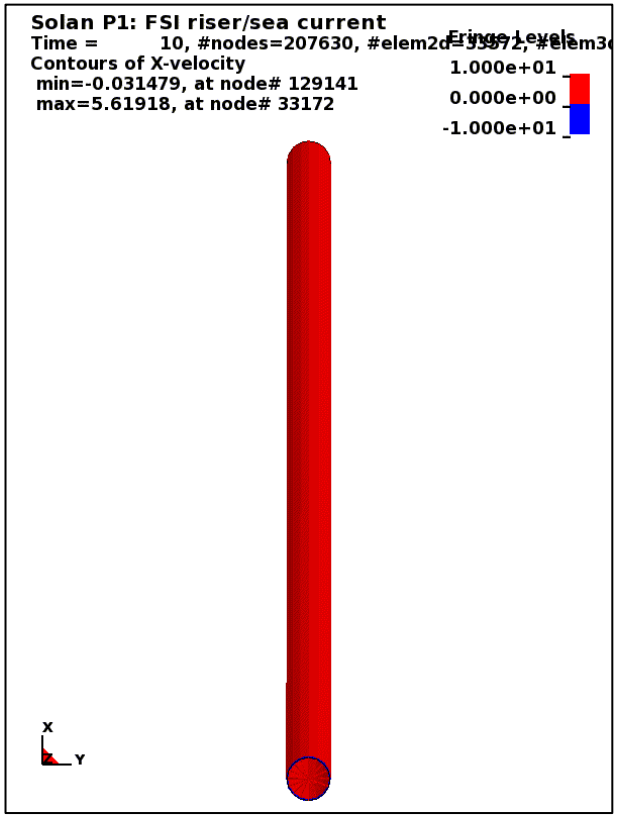
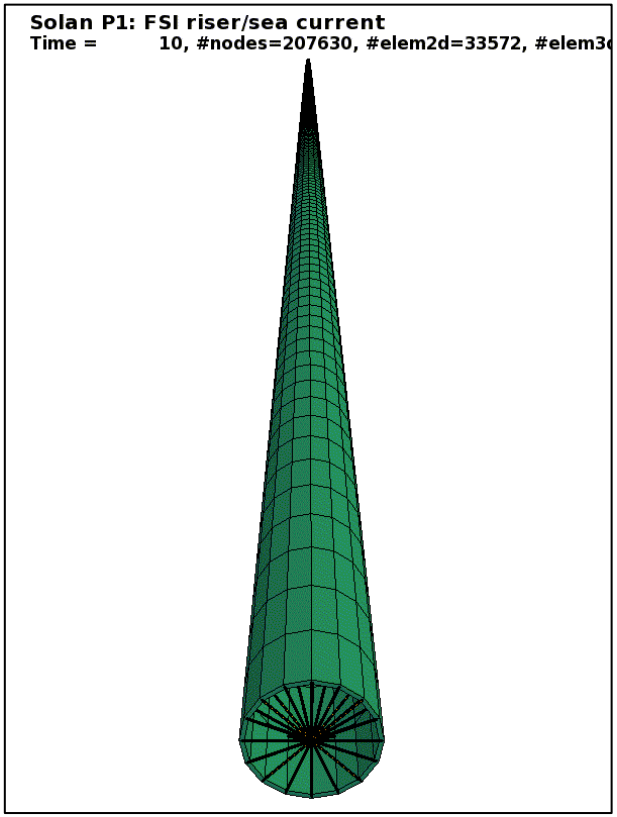
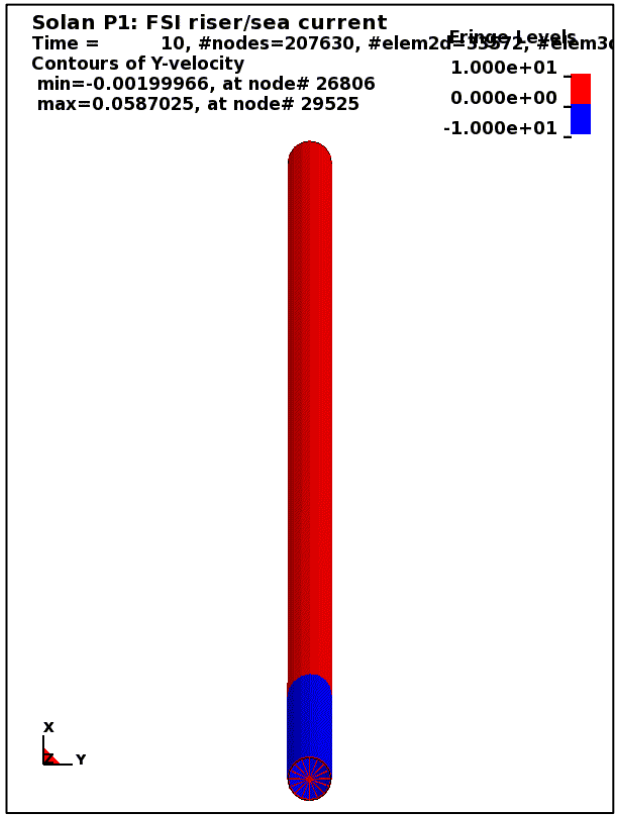
Design Analysis

- Other / Vessel or Riser Movement / Vortex induced Vibration?







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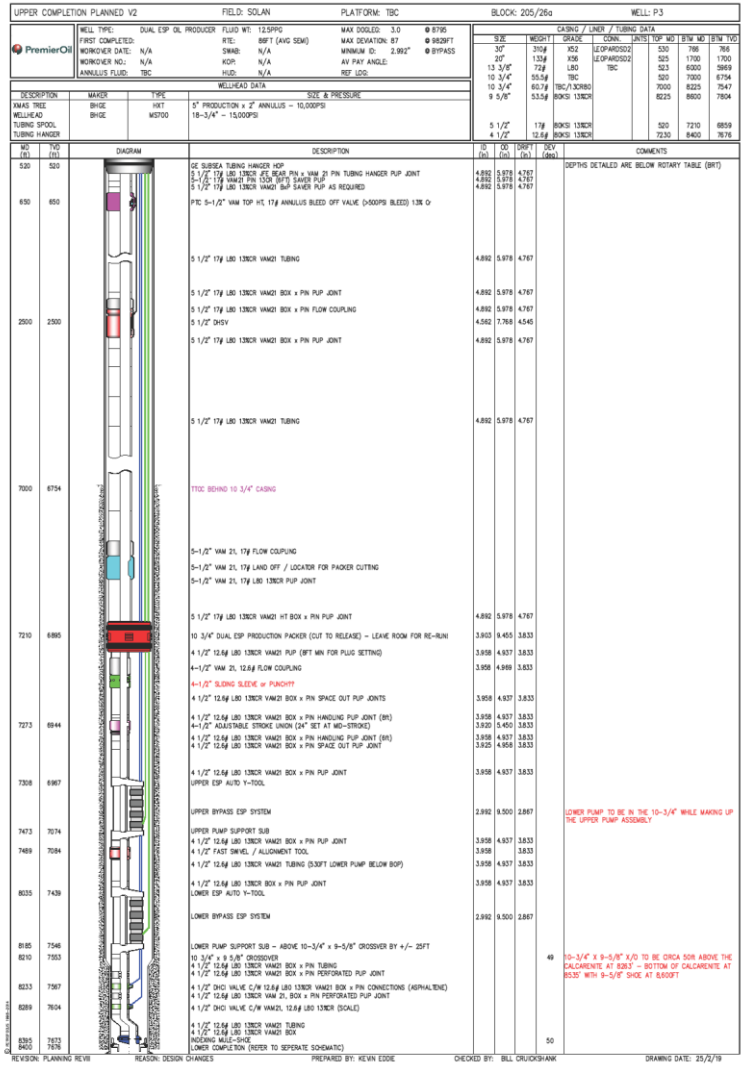
ESP Completion Design

- Distance between Lower Y-Tool and Upper Pump Support block increased from 67ft to 530ft
- Pump Sub length increased to allow flexibility in the system
- Deflection force decreased to an 1/8 of previous levels



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Theory complete!

- At this point we had:
  - ESP equipment selected and in manufacture
  - Bypass Clamp design completed and qualified
  - ESP Bypass system (dual Y-Tool) manufactured
  - Engenya Design Analysis complete

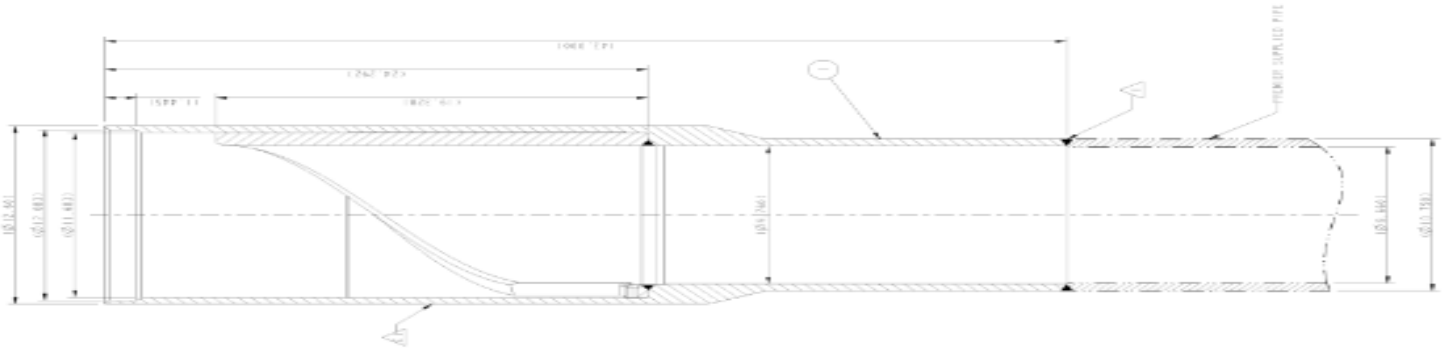
- Everyone was happy with the theory

- Time to put it into practice!

P3 Stack Up Trial

- Conducted at Franks test rig (now Expro) in Aberdeen
- The main purpose was to:
  - Trial alignment
  - Run the ESP through the Helix
  - Install new clamps
  - Test the SCLMA
  - Record lessons/create procedures

Helix Sub



Helix back from Manufacturing

Helix with 10-3/4” pup welded on

Helix in action with pump support block

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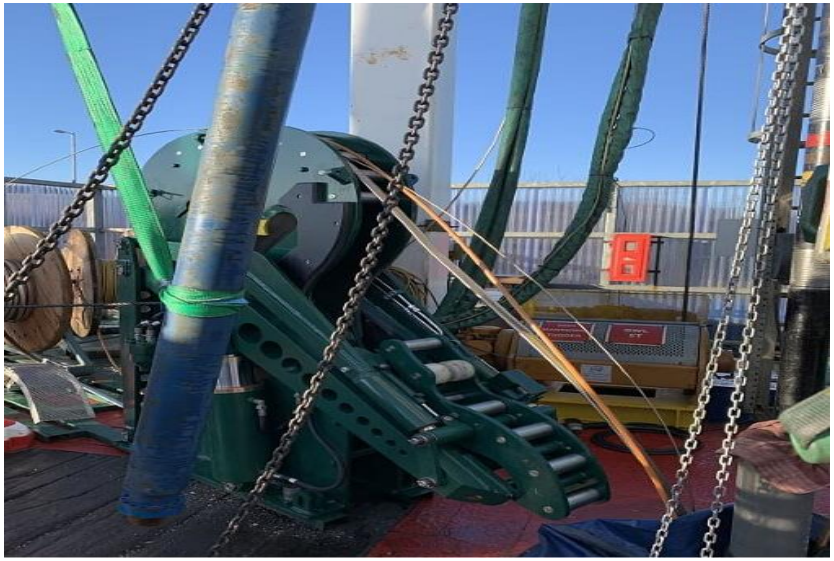
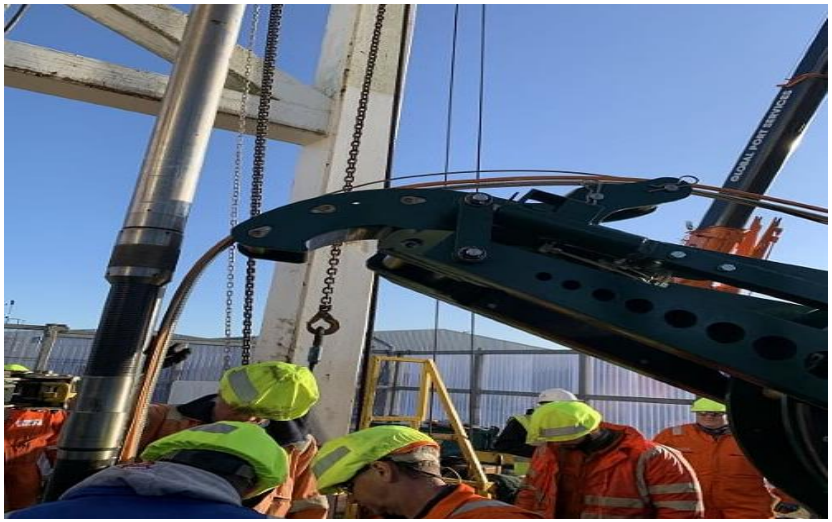
SCLMA





- SCLMA had 3 lines
- Worked great with back tension spoolers
- Lifts lines out the way for installing clamps
- Shear guillotine with remote
- Reduces manual handling of the MLE’s

Stack Up Round-up

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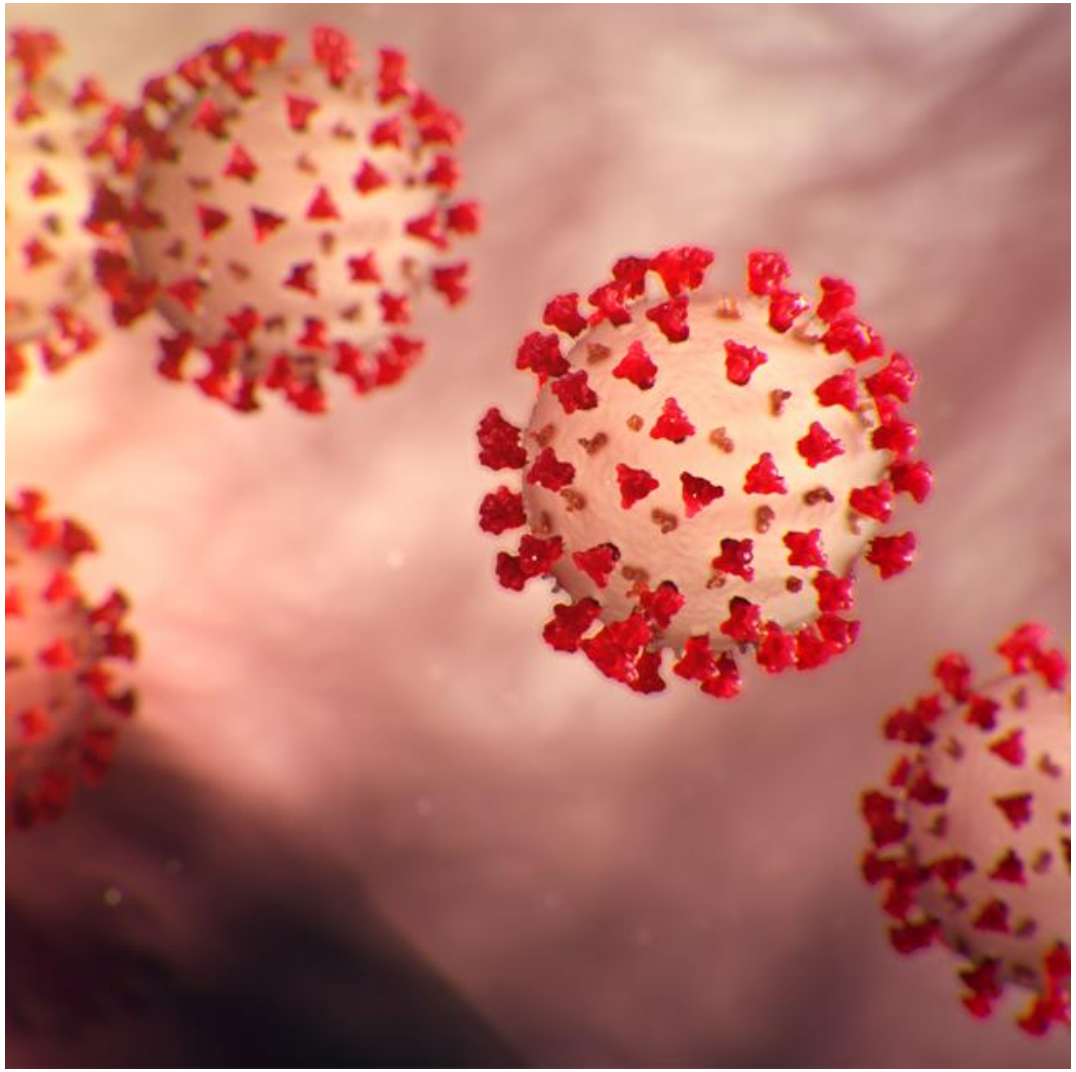
Other Issues during Project

- Pressure limitations on cable system
  - Multi scenario testing (pre drill) flagged a potential issue with certain scenarios causing large differentials
  - This caused issues with the testing and bleed downs required for the completion
  - This was dealt with by both Baker Hughes and RMSpumptools and a sensible solution was reached

- Cable Penetrator Hysteria
  - An ‘issue’ was flagged by a third party to Harbour Energy about the electrical penetrators
  - Mass panic ensued….
  - The ‘issue’ was categorically disproven

Spanners in the works…..



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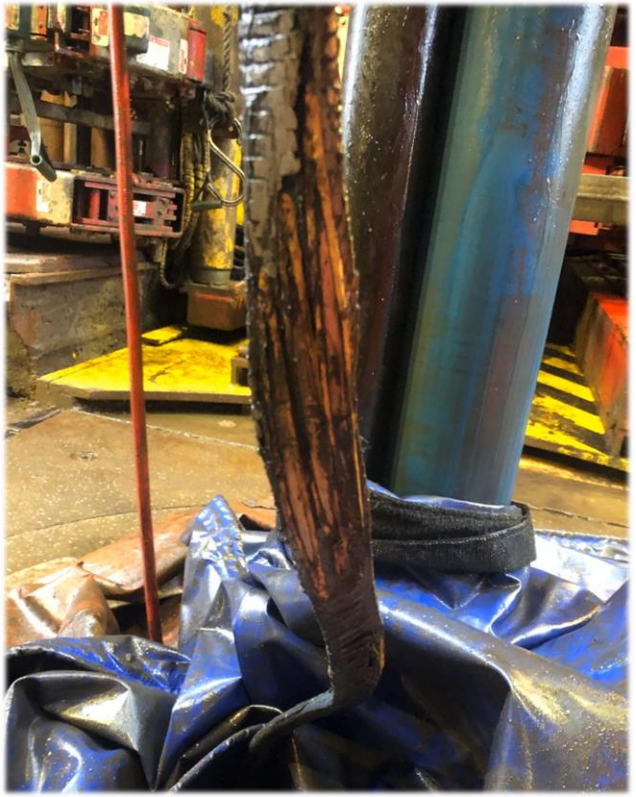
Covid Impact

- Remote inspections (videos, live feeds etc) had to be put in place quickly
- ESP string inspection was unable to be witnessed
- ESP shipping preparations were unable to be checked
- ESP installation equipment, including spares and consumables, were unable to be verified
- POB limitations offshore

The Real Deal

- There were some issues encountered…
  - Incident when a BPT joint was damaged, the ESP hung up at surface
  - Lost readings through the subsea umbilical. when the ESP was landed
    - Electrical readings were unable to be taken when landing
  - The MLE was destroyed by abrasion



The Real Deal – take two

- MLE markings didn't tally up perfectly with the ESP

- Run number 2 was a success!
- The well was completed with a Dual ESP as planned

P3 Learnings

- More provisions for electrical testing through Subsea umbilical had to be made to ensure integrity when landing
  - We ironed out a lot of this on Run 2
- Communication must be maintained at ALL times – this was the root cause of the BPT incident

- Base all MLE marking on actual measured lengths. Keep markings to a sensible minimum
- Bypass Tubing Lengths should be determined after the ESP design is finalised. Handling and 'stick up' should be planned

Future Workover Considerations

- Consider a POD system?
- Reduce the intermediate tubing?
- If radical changes were to be made:
  - Engenya model would be updated
  - Stack up testing would be carried out
- ESP running Rig availability

General Conclusions

- Don’t have a global pandemic during a project…
- Engage help early
- Design for success
- Give the project ample time
- If hindsight is available – USE IT!
- If an assurance is available – TAKE IT!
- Prepare for the worst – full back ups and alternative plans

Collaboration was key!

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Questions?

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