



Challenges encountered during the design of a CO₂ injection well for a depleted reservoir

Roel Roijmans, Alice Sorbier, Willem Maarten van Haaften, Rob Grauwmans
K14-FA-2 team

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Summary

- This presentation will cover the completed detailed design of a well designed for injecting CO₂ into a depleted reservoir.
- The novelty of this presentation will be that it covers a completed piece of work, in which all possible thermal loads cases (not just transient shut-in or blow out, but all scenarios) during the well life were considered using the OLGA-WellCat workflow.
- Material selection related to CO₂ contamination will be addressed.
- Annular pressure management during well life will also be addressed.

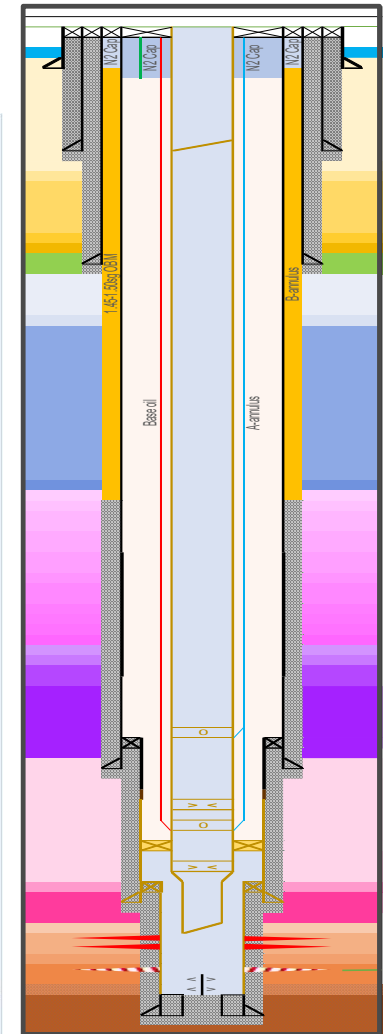
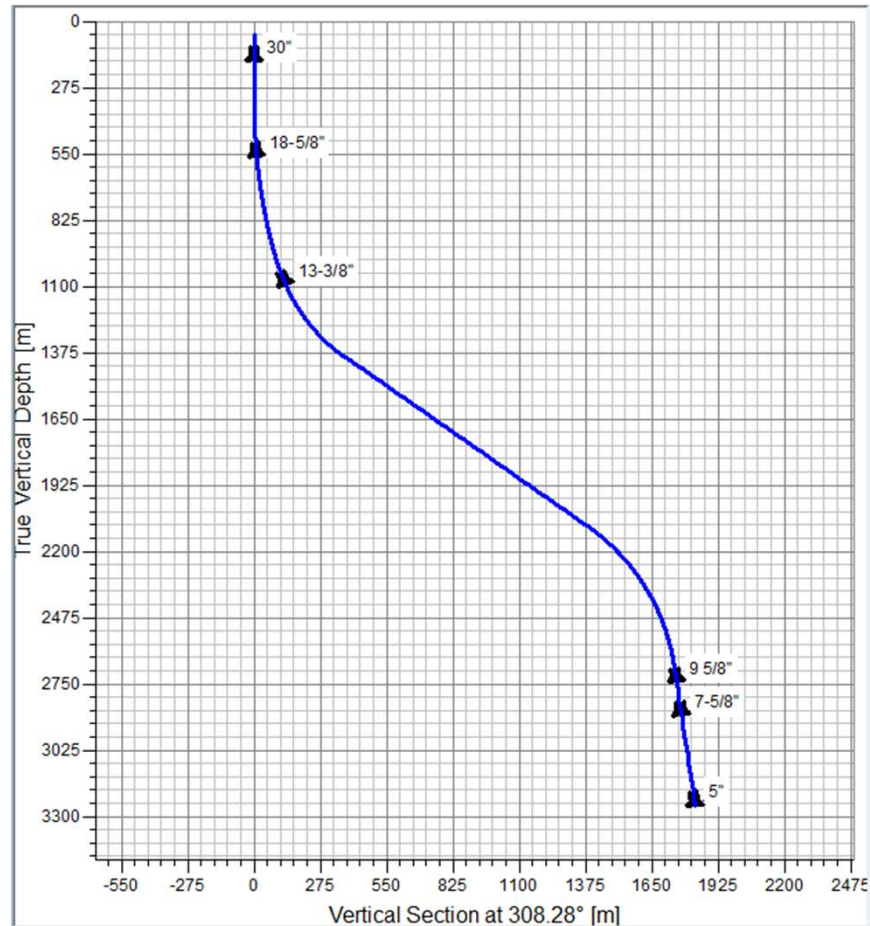
Introduction

- The Launch Stores project is focused on realizing offshore CO₂ storage under the seabed of the North Sea.
 - Capacity: aim to transport a minimum of 5.0 Mtpa of CO₂ per year.
 - The maximum capacity of the project is 22 Mtpa CO₂ per year – design limit trunkline.
- The project includes a ~200km trunkline connecting the onshore Maasvlakte hub with offshore stores.
- The Shell launch store will be the re-development of the K14-FA depleted gas field, into a CO₂ storage site. Shell plans to drill new CO₂ injection wells from a still to-be-installed new platform.

Well Concept Design

- S-shaped well (max incl. 55deg)
- 6-string design
- Dedicated liner for Zechstein

Hole size	Casing size	Section TD Criteria
N/A	30"	100mBML
24"	18-5/8"	In top North Sea clays
17-1/2"	13-3/8"	30mAH into Vlieland Claystone
12-1/4"	9-5/8" x 10-3/4" x 9-5/8"	25mAH into ZEZA
8-1/2"	7-5/8" x 7"	5mAH into ZE1W
6"	5"	Carboniferous



Operational scenarios during CO2 injection

Planned Scenario	Preceding Operation
Initial Conditions	N/A
Start-up of injection	Ambient
Steady state injection	Start-up of injection
Shut down of injection	Steady state injection
Hot wash	Ambient
Controlled boil off above SSSV	Steady cold injection
Shut-in, Geo	Shut down of injection

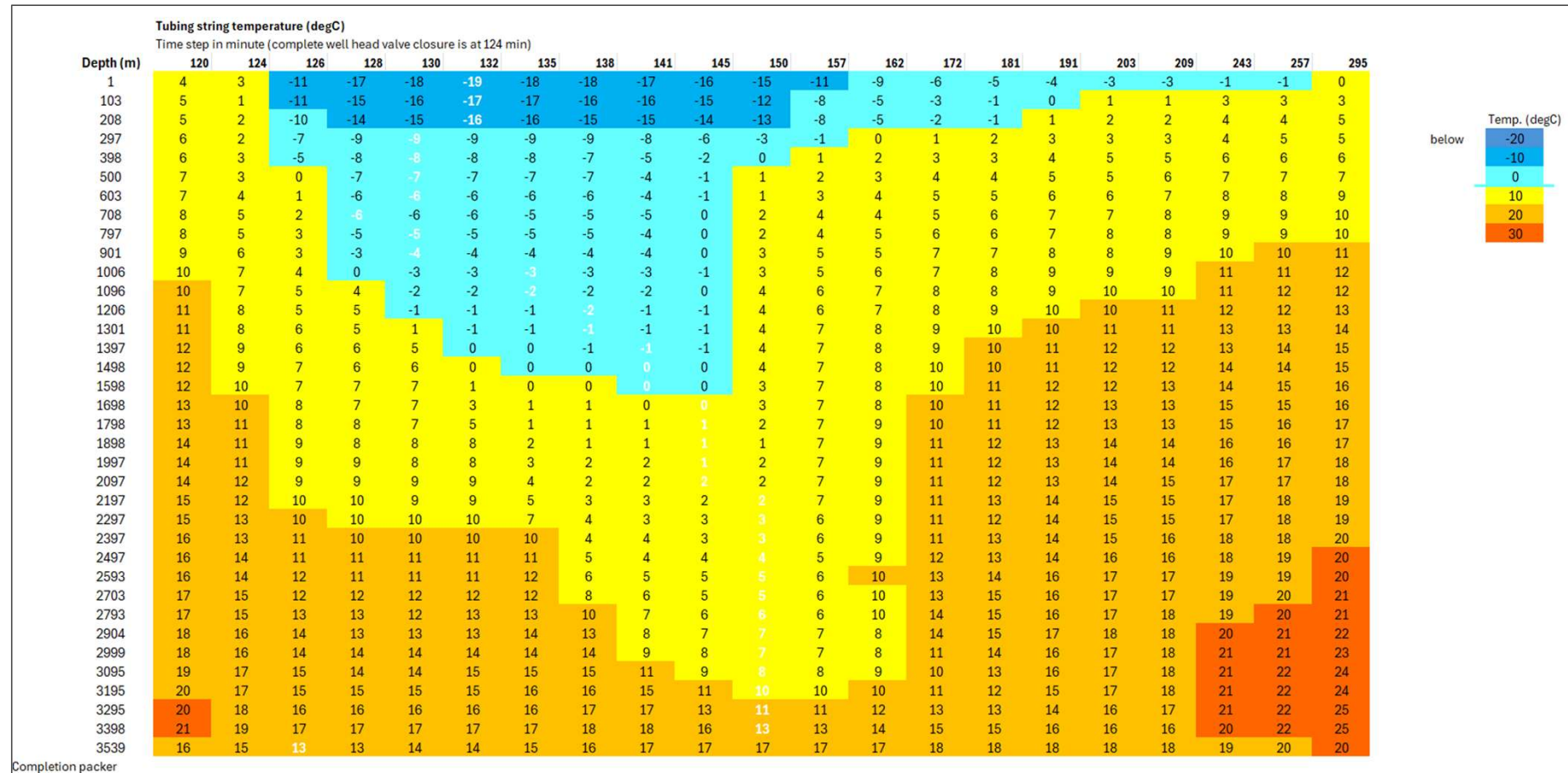
Unplanned Scenario	Preceding Operation
Uncontrolled boil off above SSSV	Steady state injection
Controlled leaking SSSV	Controlled boil off above SSSV
Uncontrolled leaking SSSV	Uncontrolled boil off above SSSV
Uncontrolled boil off to tail / nipple	Steady state injection
Full tubing evacuation / uncontrolled boil off to perforations	Steady state injection
Continuous tubing blow-out	Steady state injection
Continuous casing blow-out	Pull tubing
Tubing Leak	Steady state injection

- Operational scenarios modelled in OLGA:

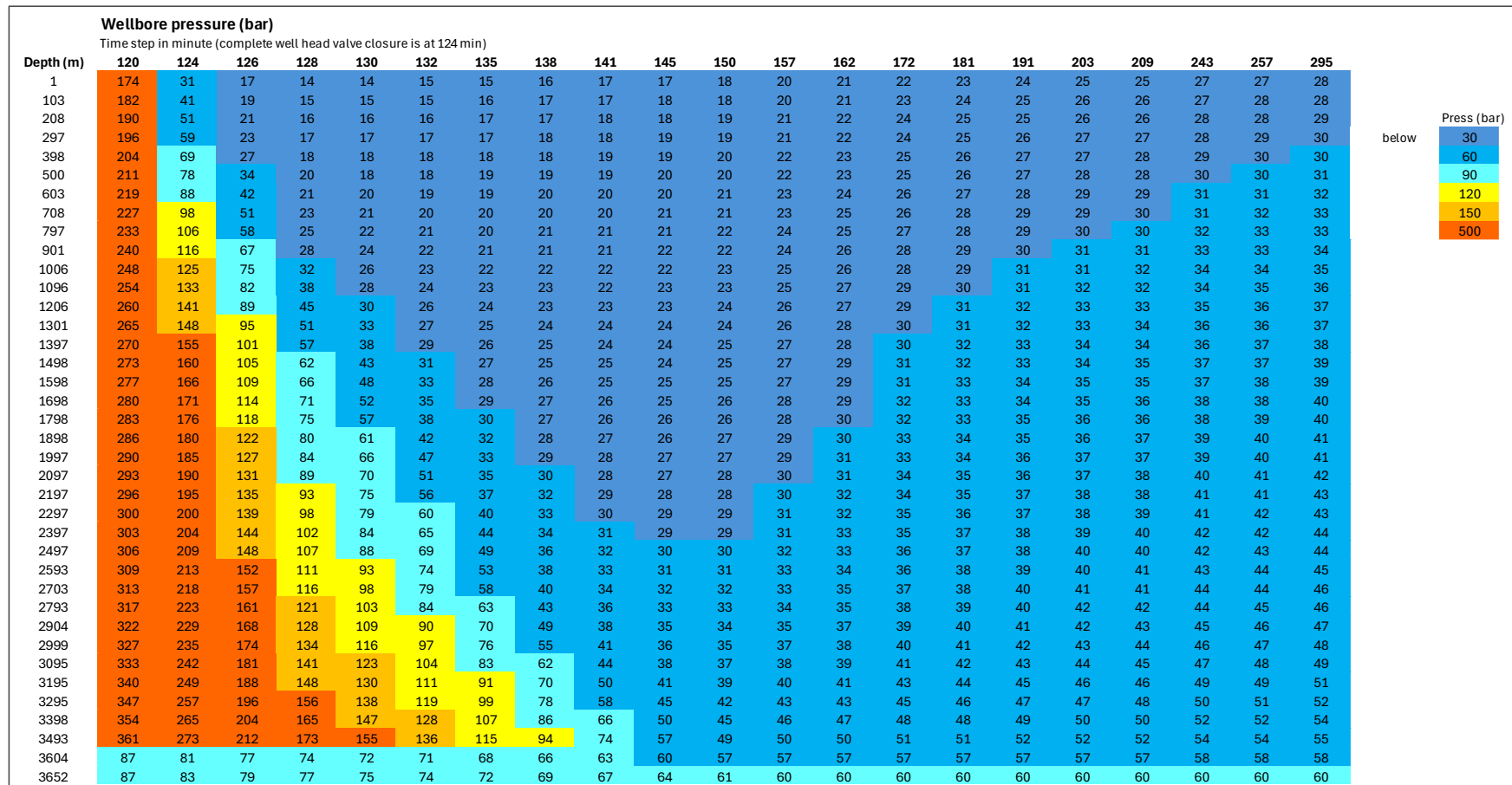
- Early-, mid-, and late-life
- Various reservoir properties
- Various CO2 arrival pressures

- Resulting temperature and pressure profiles were subsequently loaded into WellCat

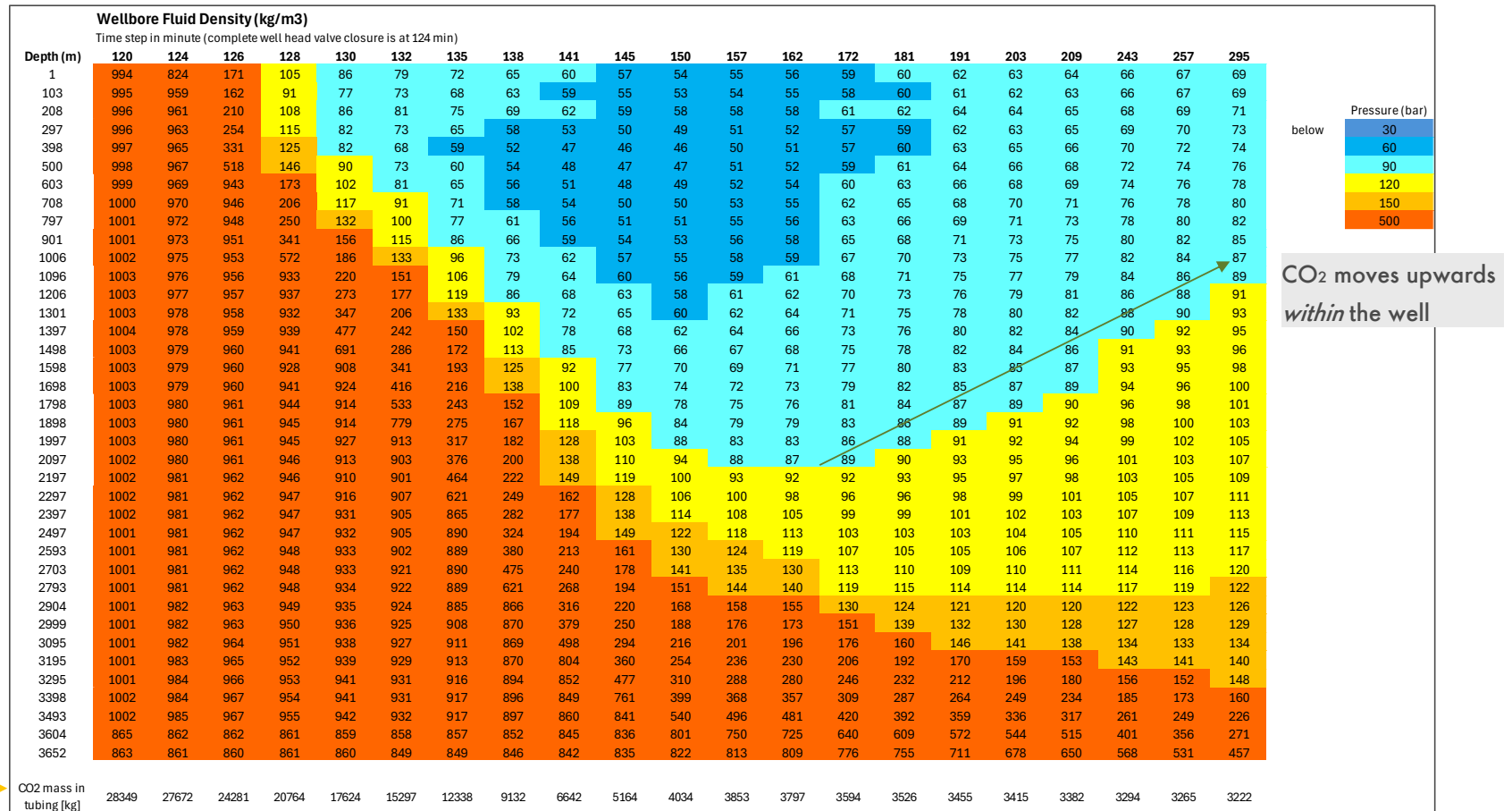
Zoom-in on planned Transient shut-in Scenario - temperature



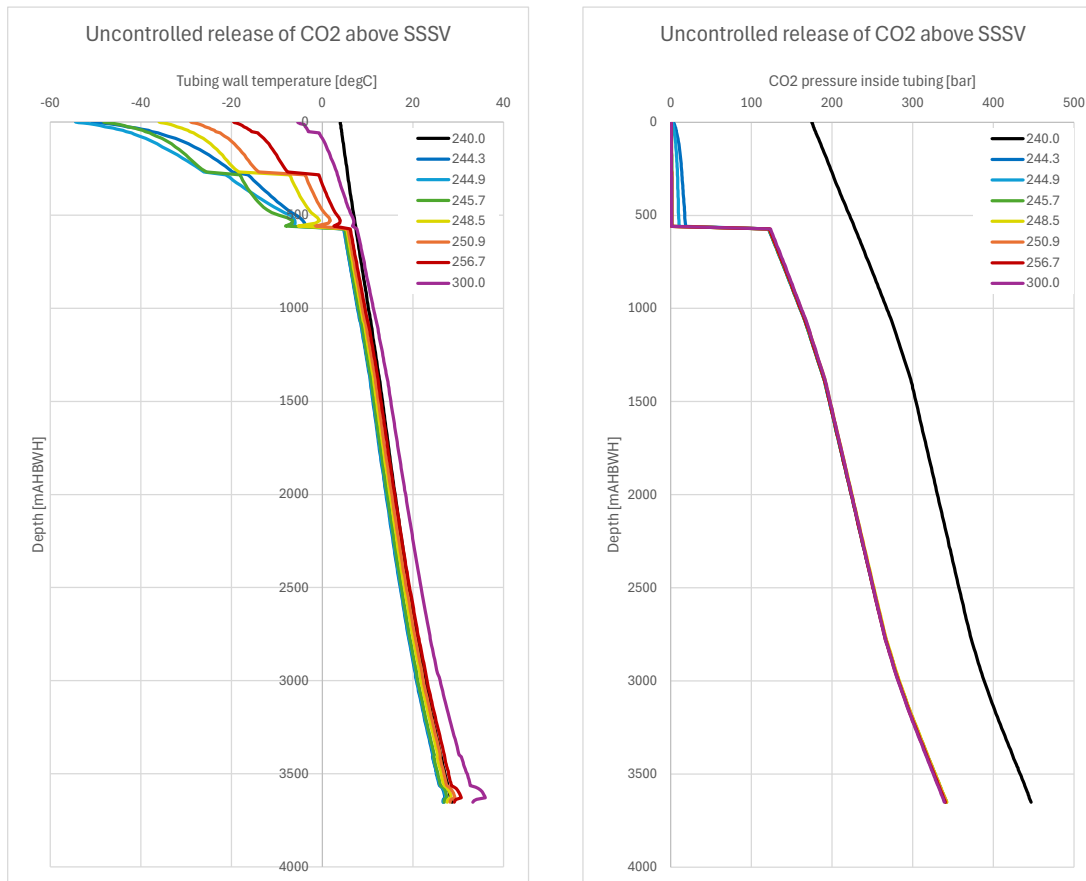
Zoom-in on planned Transient shut-in Scenario - pressure



Zoom-in on planned Transient shut-in Scenario - Density



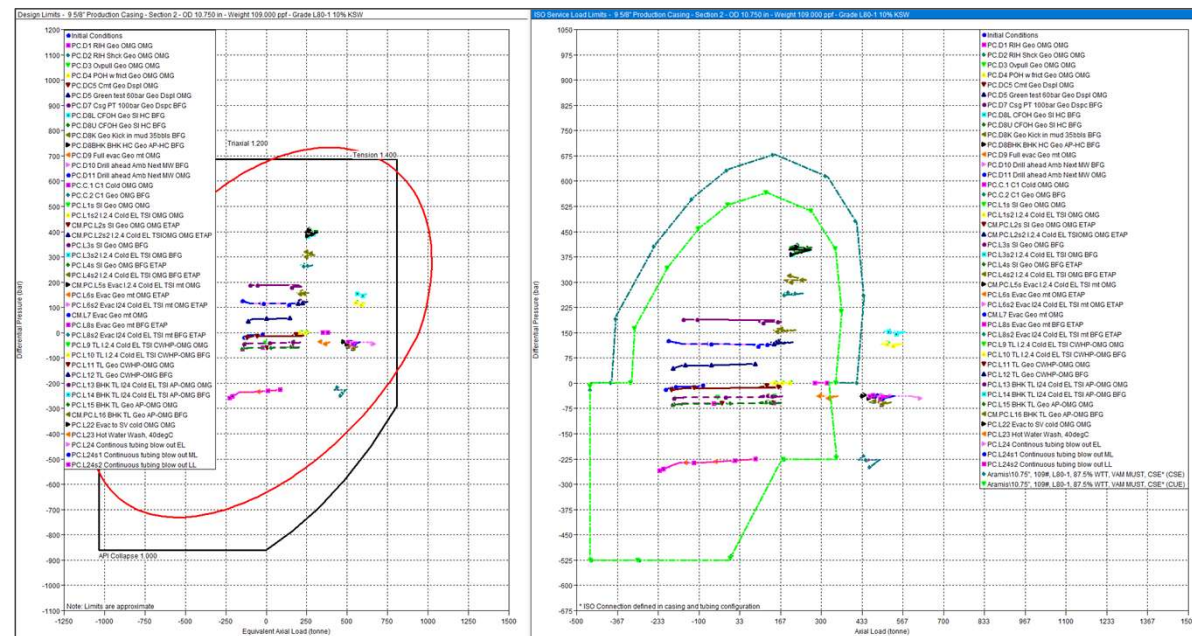
Zoom-in on unplanned released above SSSV



- Temperature profiles for tubing wall (not for the CO2 itself) & CO2 pressure profiles versus depth for different time steps (in minutes) during an uncontrolled release of the CO2 above the SSSV, as per OLGA modelling.
- Curves:
 - Black (240min): steady state injection
 - Light blue (244.9min): coldest average temperature profile,
 - >244.9: well warms back up.

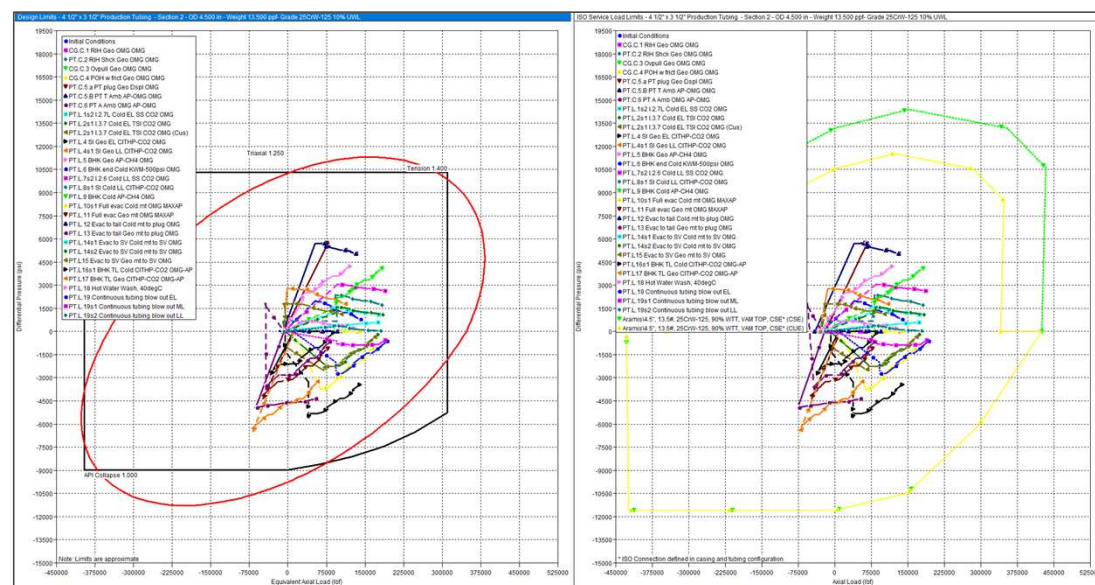
WellCat results (1)

- No issues with surface & intermediate casing. Shielded from the cold by the production casing.
- Production casing 9-5/8" x 10-3/4" x 9-5/8": Normally L80 with **MUST** section across squeezing salts, as per below plots. But **MUST** connections too weak to handle planned operational scenarios like the early life transient shut in.



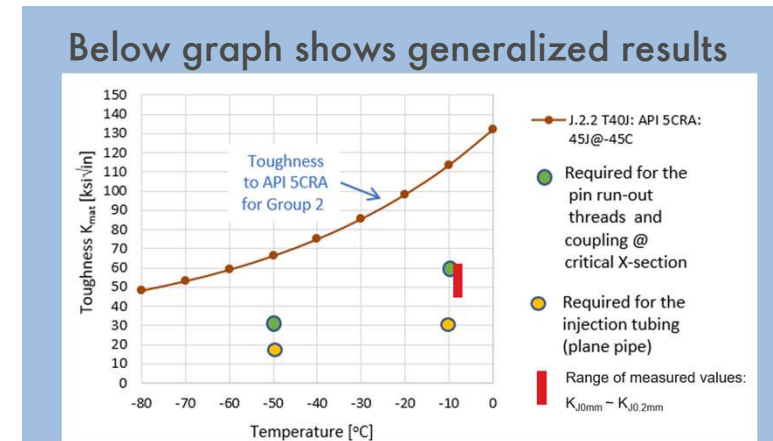
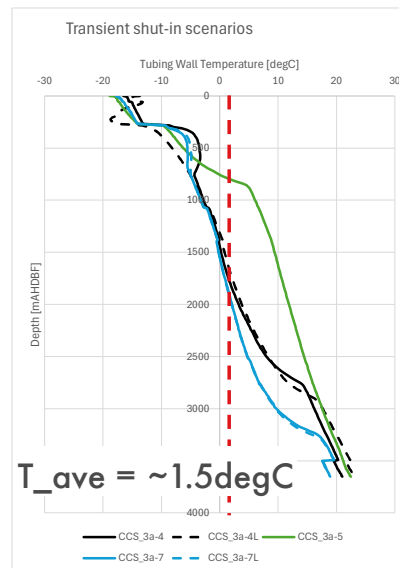
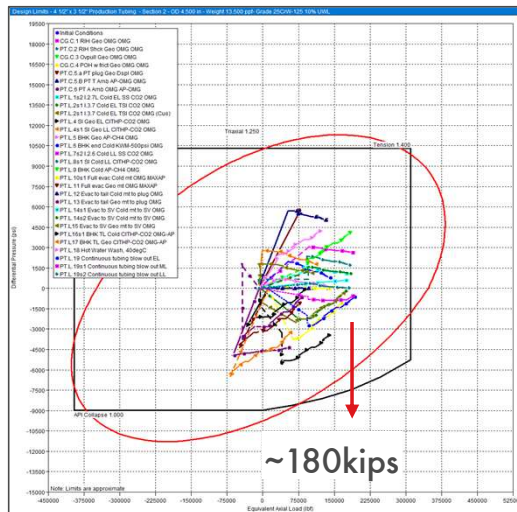
WellCat results (2)

- The 7in liner is a crossed over string from L80 MUST above the packer (squeezing salts) and SM2535 below the packer (flow wetted).
- No issues with 5in liner across the reservoir.
- For the tubing, 25CrW-125 selected.
 - All loads pass easily, as per the plots.
 - However, various other challenges with tubing.



Tubing material selection

- High stresses in tubing are mainly due to 1) tubing weight & 2) significant cooling in transient scenarios.
 - Low temperature of the tubing steel is caused by the CO₂ changing phase from liquid to gas.
 - Hydrogen (up to 7500ppm) is one of a contaminants in the CO₂ stream.
- Adequate material toughness under combined high-stress, low-temperature, and H₂ exposure uncertain.
- Key risk: Low temperature Hydrogen embrittlement of 25CrW-125 completion tubing**



Annulus Management

N₂ cap placed in B- & A-annulus. Objectives:

1. Avoid air ingress
2. Allow for pressure monitoring

○ A-annulus

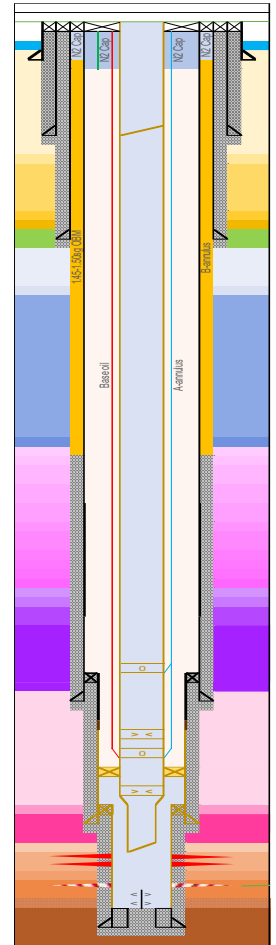
- Initially filled with base oil
- Placement N₂ cap: capillary line through WH..

○ B-annulus

- After cementation, B-ann. filled with cmt, spacer, & OBM (ok for low T).
- Placement N₂ cap: Bleed off OBM as drilling subsequent sections; place N₂ cushion as the well cools.

○ C&D-annulus

- Both cemented to surface, so, no need for annulus management.





Q&A

