Flexible Couplings (FC)

for Thermal Stress Mitigation of Casings for Geothermal Wells

DEEPLIGHT - Novel concepts to construct cost effective geothermal wells with Electro Pulse Power Technology

Consortium Meeting, February 27, 2025

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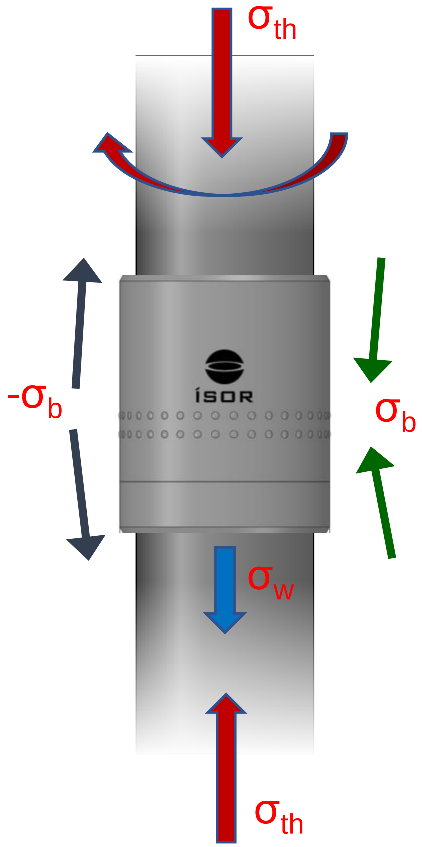
The contents of this presentation reflect only the view of the author(s) and do not necessarily reflect the opinion of any of these funding agencies.

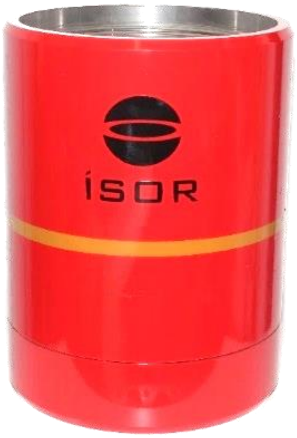
Objectives of FC in DEEPLIGHT

- Investigation of the potential of using novel EPP-CwD technologies in high-temperature geothermal applications.
- Investigation of using novel casing connection Flexible Couping (FC) along with EPP-CwD for high-temperature geothermal areas.
- Carry out representative test for Flexible Coupling at ambient temperatures in relation to operational loads of CwD with EPP technology.



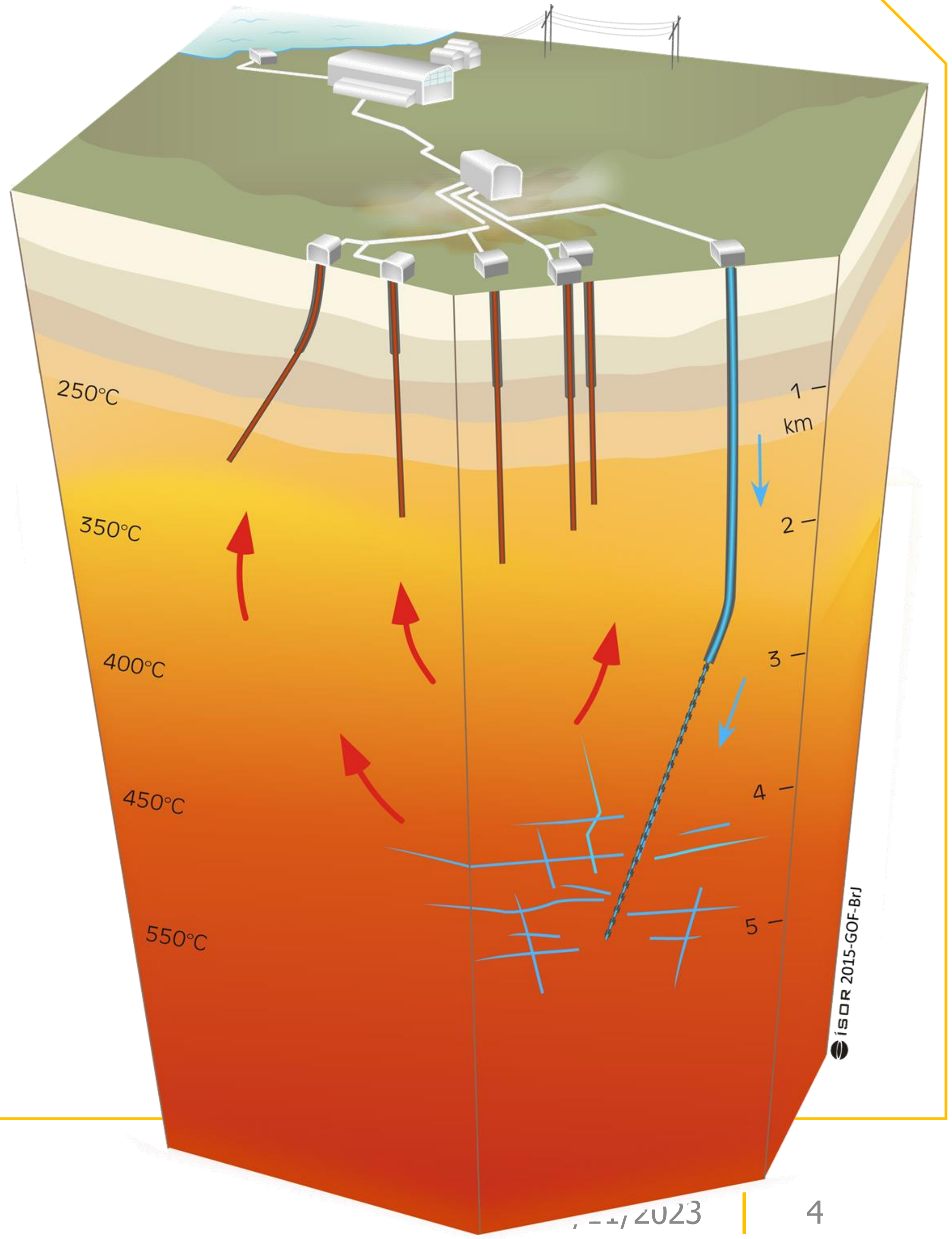
The Flexible Coupling – Expansion Joint

- The novel patented technology of Flexible Couplings has been in development at ÍSOR since the year 2015
- The idea is based on research on casing failures in Iceland and around the world
- Have been function tested at ambient and high-temperature and pressure conditions
- Flexible Couplings were installed in a production casing in a high-temperature well that is currently being drilled in Nesjavellir, Iceland in February 2025
- Are not yet commercially available



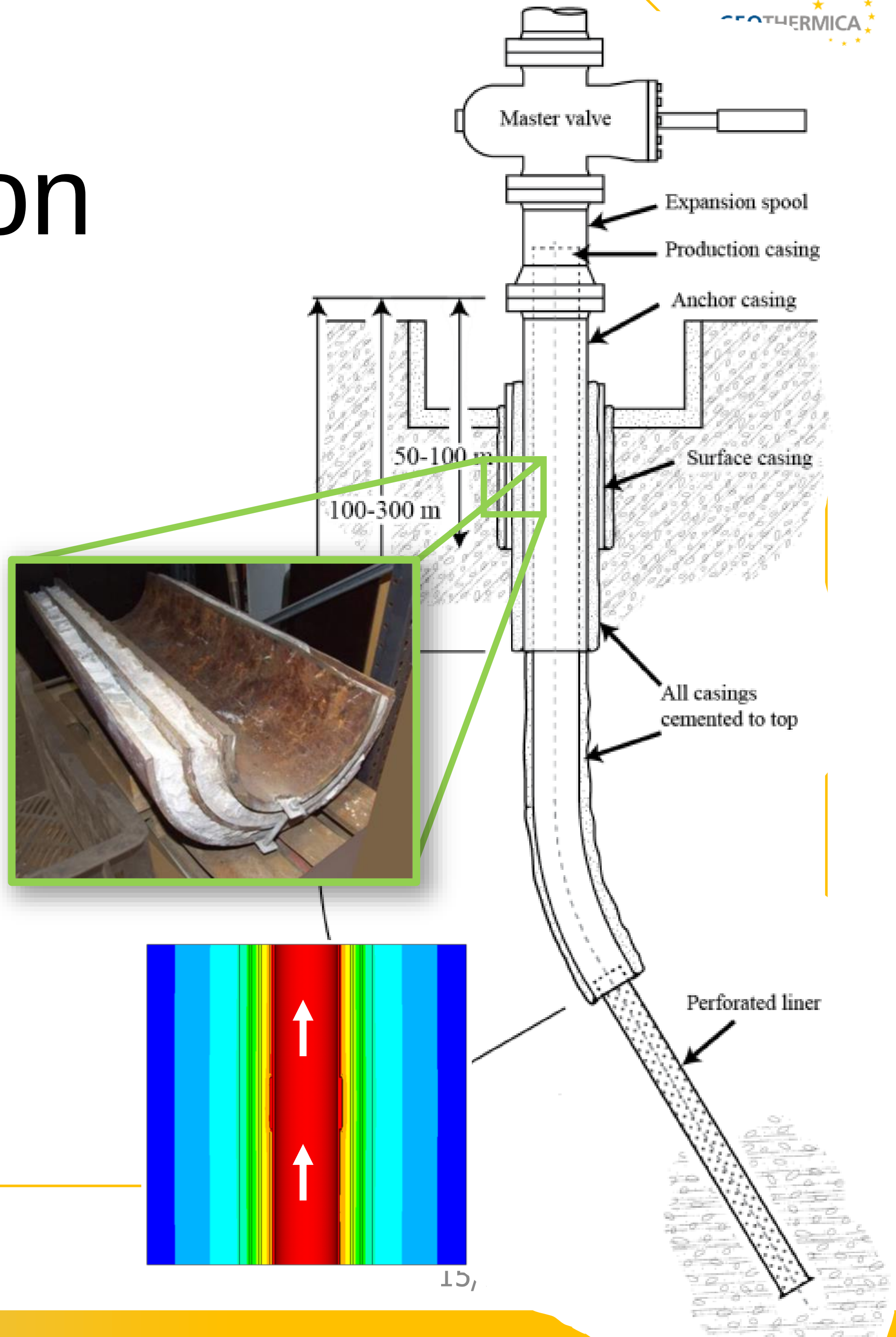
Introduction

- State-of-the art well design of high-temperature geothermal wells is up to a good standard and practices
- However, casings in high-temperature wells (>200°C) are prone to fail due to various factors
- The main casing failure modes have been identified as casing collapse and axial tensile failures
- Casing problems generally increase as temperatures increase
- R&D work is currently ongoing within ÍSOR with the objective to mitigate these failure modes to increase the reliability of High-Temperature Geothermal Wells and enable drilling to Superhot conditions, e.g. KMT and IDDP



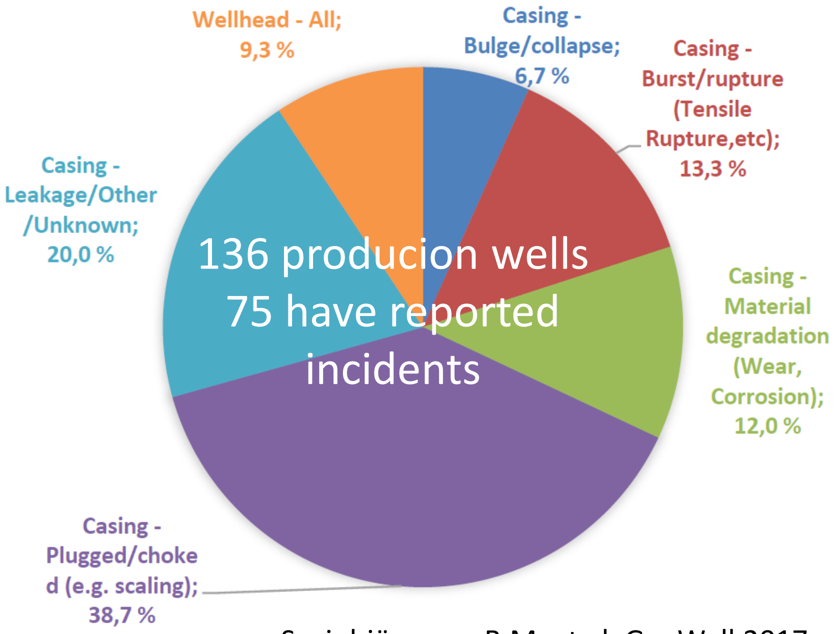
Motivation / Need for solution

- Thermal expansion of constrained casings is one of the most severe structural concerns in high-temperature geothermal wells
- When high-temperature wells warm-up, the casings thermally expand and generate stresses above yield strength, resulting in plastic strains (permanent deformations)
- In high-temperature wells ΔT is around **200-300°C**
- For ultra-high-temperature wells ΔT is higher **400-550°C**



Need for improved casing design for HT-wells

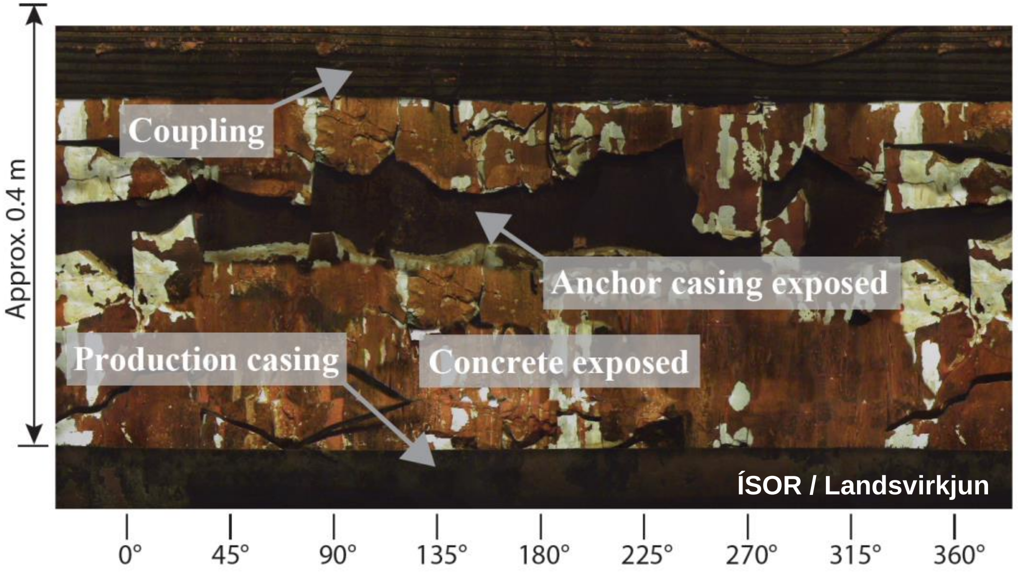
- A study in EU Horizon 2020 project GeoWell showed that out of 136 high-temperature production wells in Iceland, 75 had reported incidents
- In high-temperature wells, common casing failure mechanisms are **casing collapse** and **tensile failure** at casing connections



Sveinbjörnsson B.M. et al. GeoWell 2017

Casing collapse:

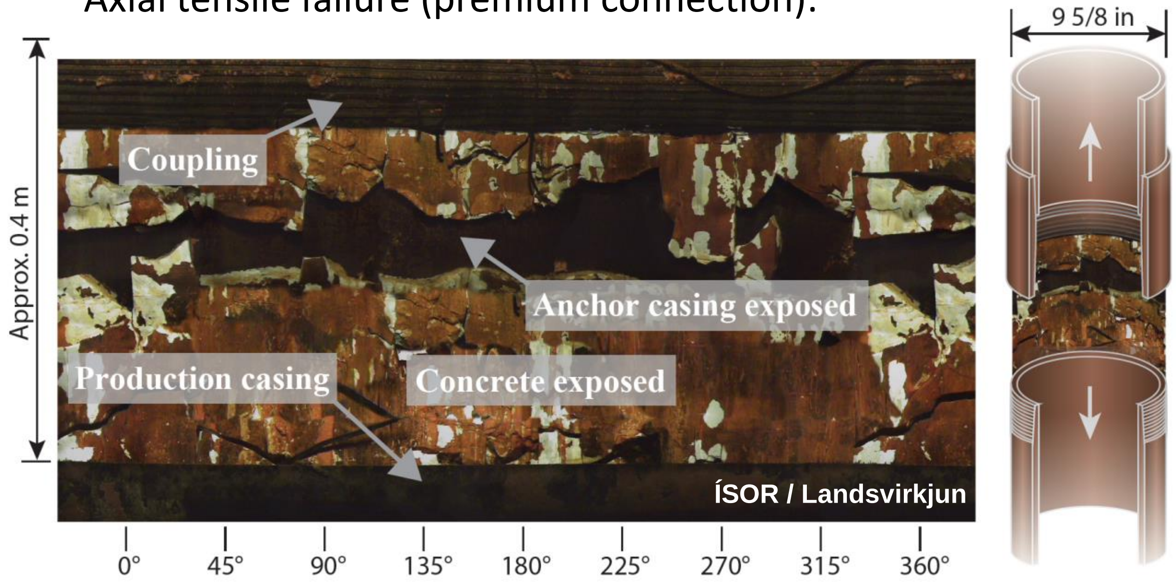
Axial tensile failure (premium connection):



Kaldal et al. 2016, *Structural modeling of the casings in the IDDP-1 well: Load history analysis*

Main Casing Failures in HT-Geothermal Wells

Axial tensile failure (premium connection):

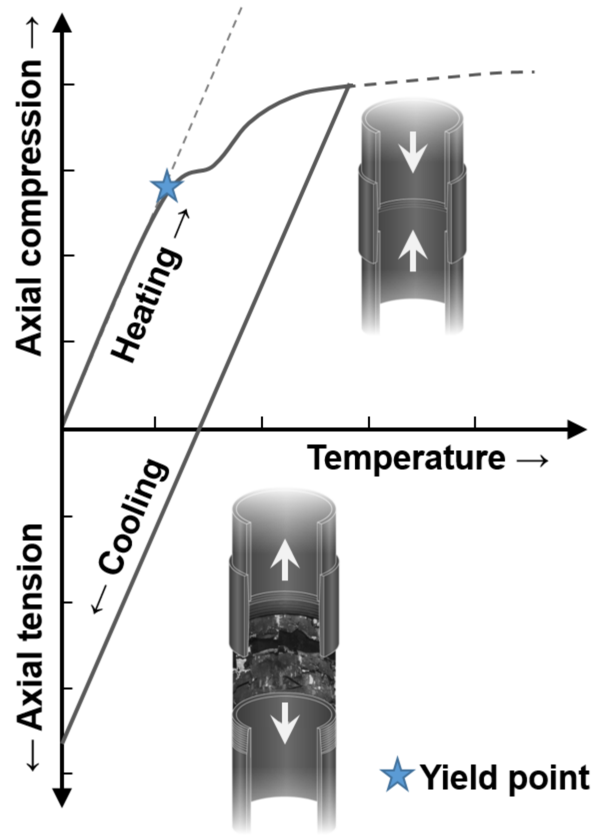


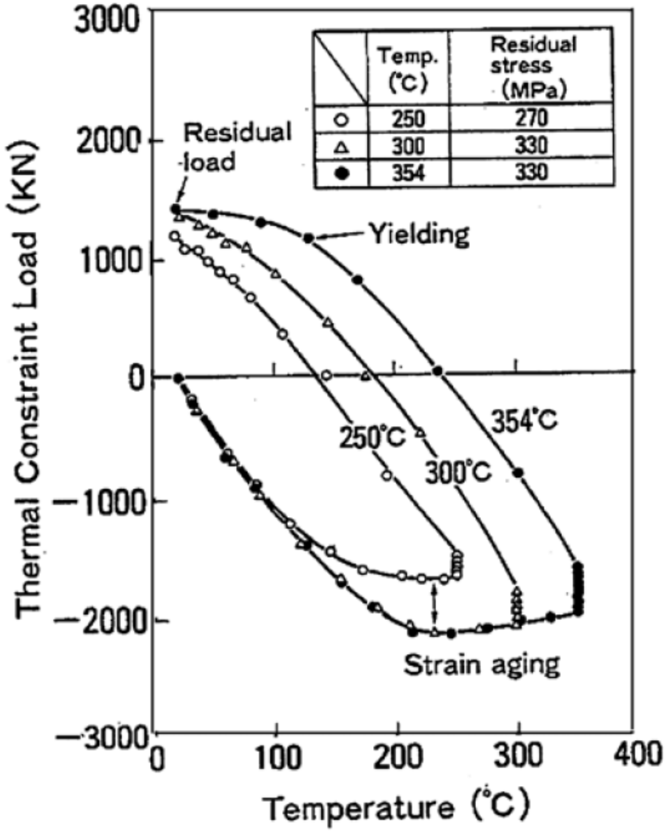
Kaldal et al. 2016, *Structural modeling of the casings in the IDDP-1 well: Load history analysis*

Casing collapse:

Causes?

Beyond the yield point both in heating up and cooling



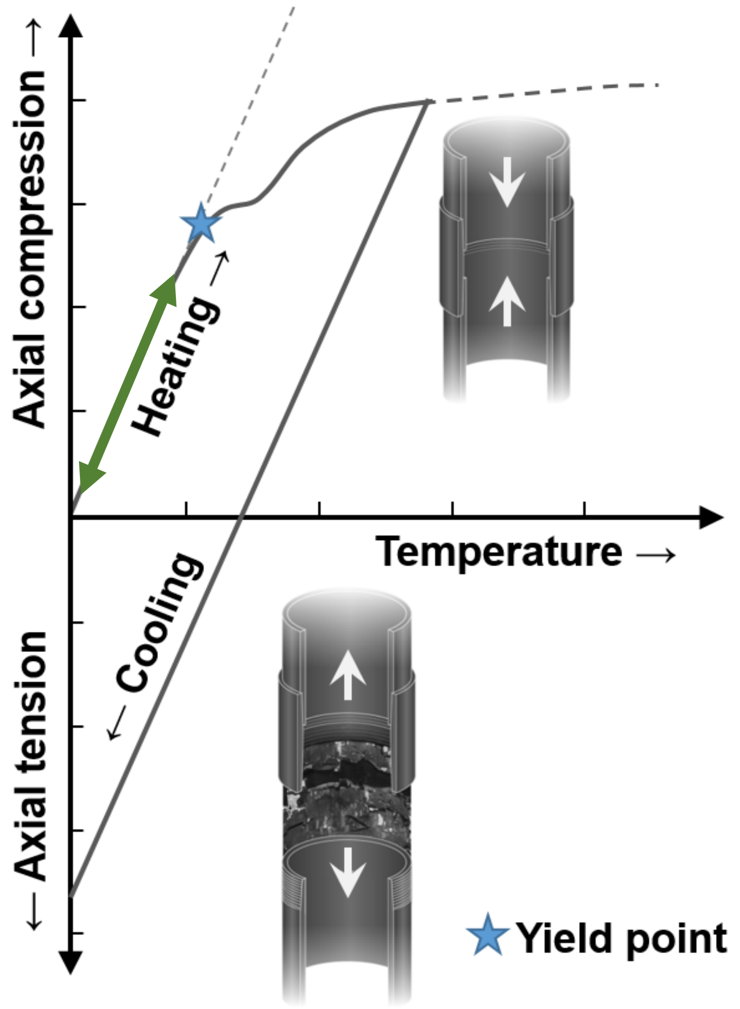


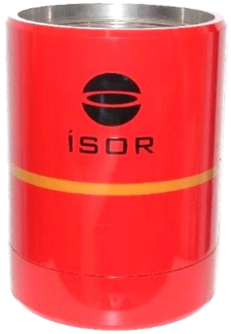
Maruyama et.al 1990 (SPE 18776)

- API K55 casing with minimum yield strength of 379 MPa, will yield at ΔT = **~150-200°C**
- API L80 casing with minimum yield strength of 551 MPa, will yield at ΔT = **~210-240°C**

The Flexible Coupling – Function

- The Flexible Couplings allow displacement to compensate for thermal expansion of the casing
- Compressive axial stresses of the casing are controlled to be within the elastic range of the material
- Plastic straining of the casing is therefore limited
- When wells warm-up the coupling takes up the casing’s expansion
- If wells need to be shut-in or injected for maintenance, the axial tension will be manageable without casing damage





Flexible couplings – prototype – testing

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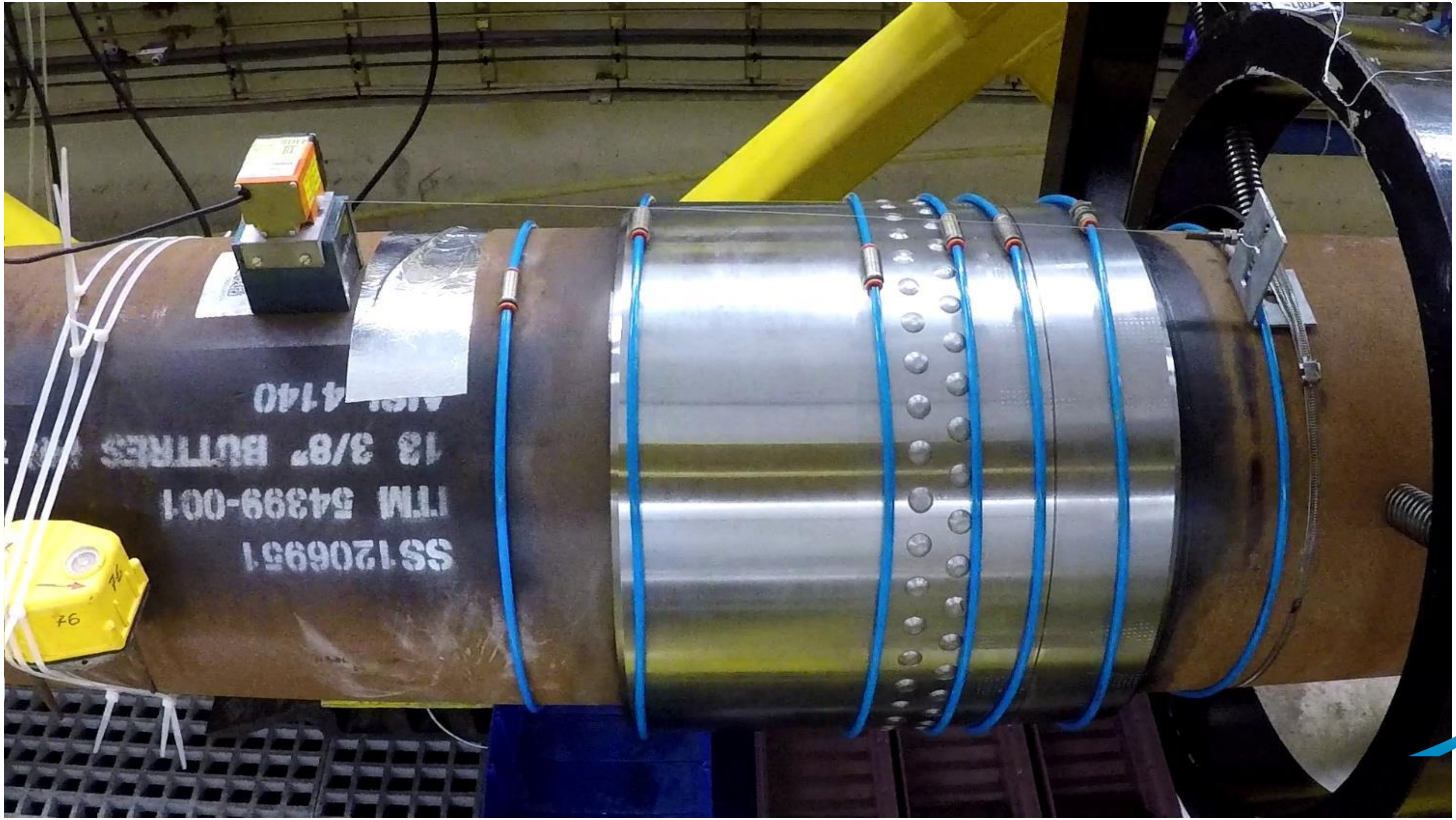

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Flexible couplings – prototype – testing

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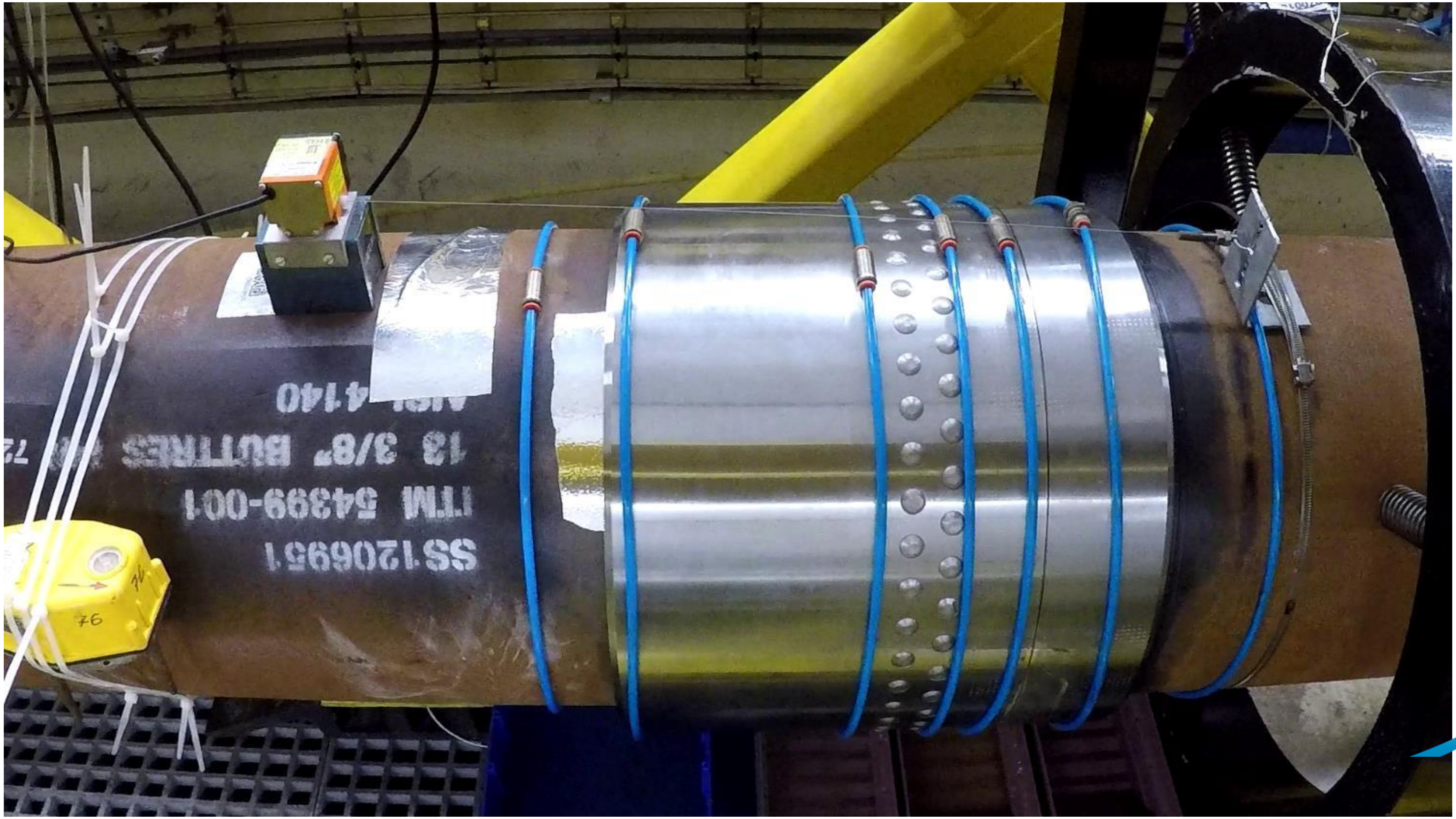

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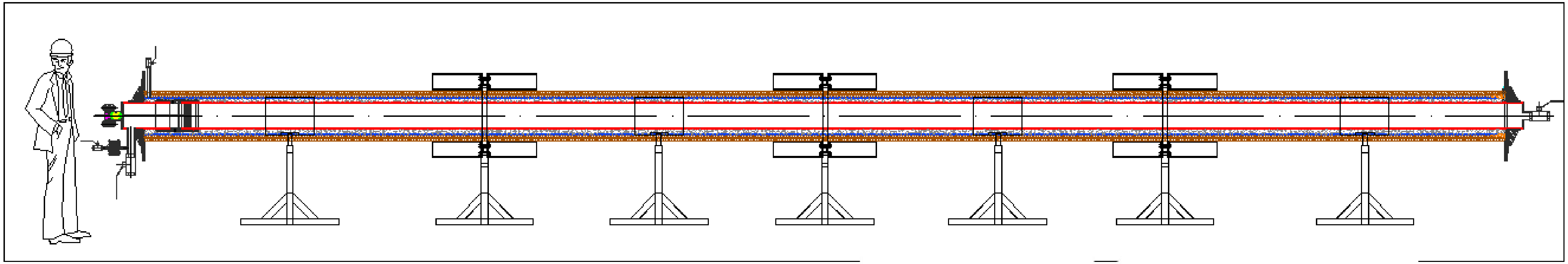
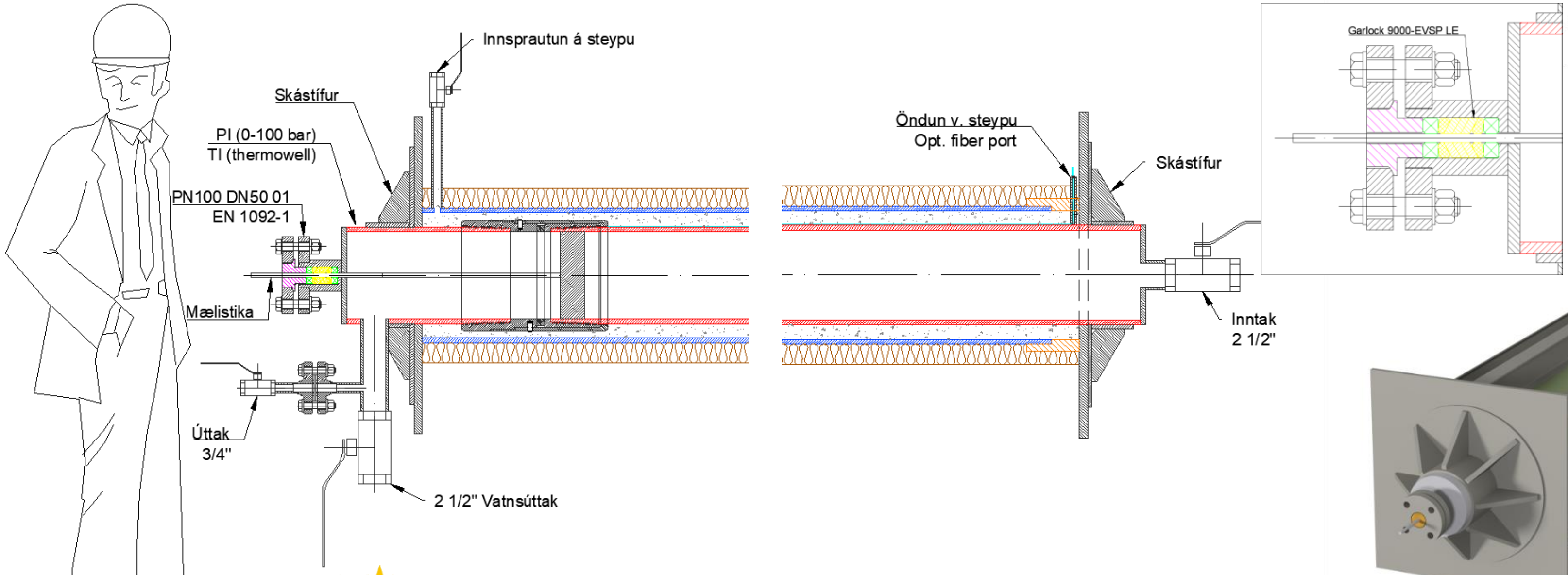
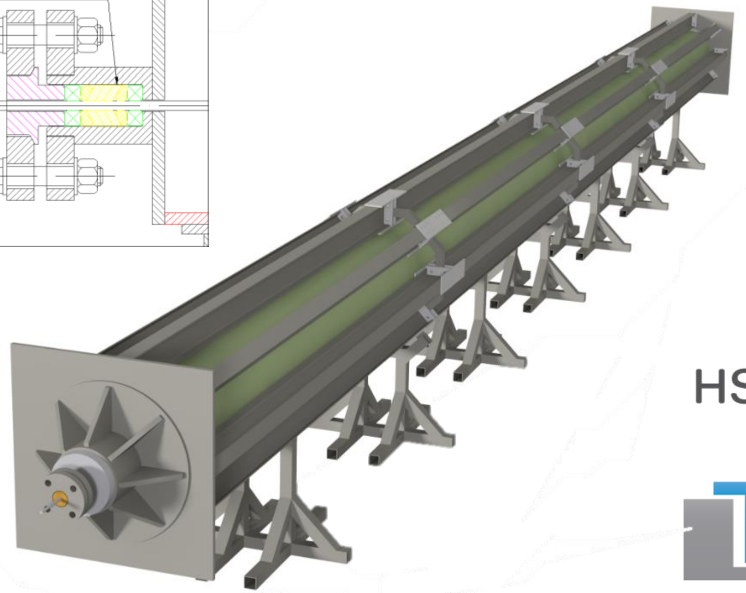
Testing at relevant environment

GeConnect ÍSOR







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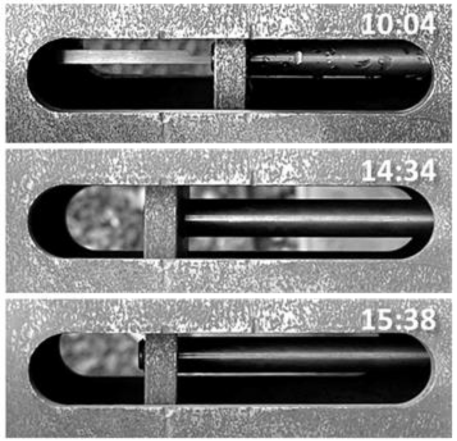
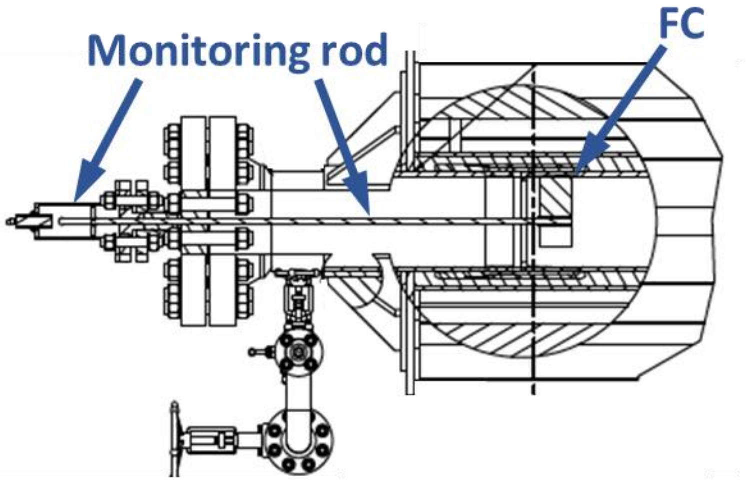
GEOTHERMICA

This project has been subsidized through the ERANET cofund GEOTHERMICA (Project no. 731117), from the European Commission, Technology Development Fund (Iceland), Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages (Germany) and Ministerie van Economische Zaken (The Netherlands)

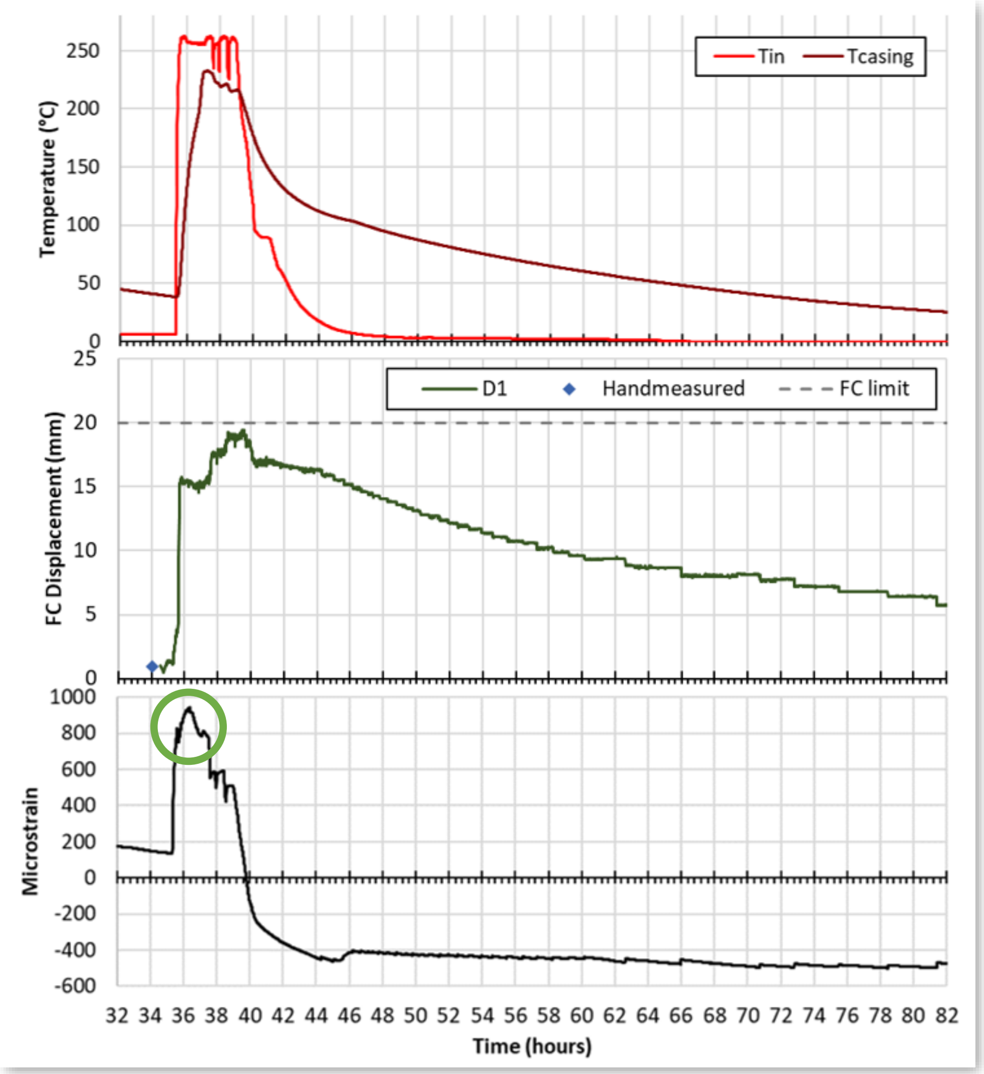
Experimental results

Results from displacement sensor measuring movement of casing into the Flexible Coupling.





Thermal cycle nr. 2 of 5. For reference onset of yield occurs at around compressive strain of 1850 με for the API K55 casing (compared to 3400 με for ΔT of 262°C for a fully constrained casing):



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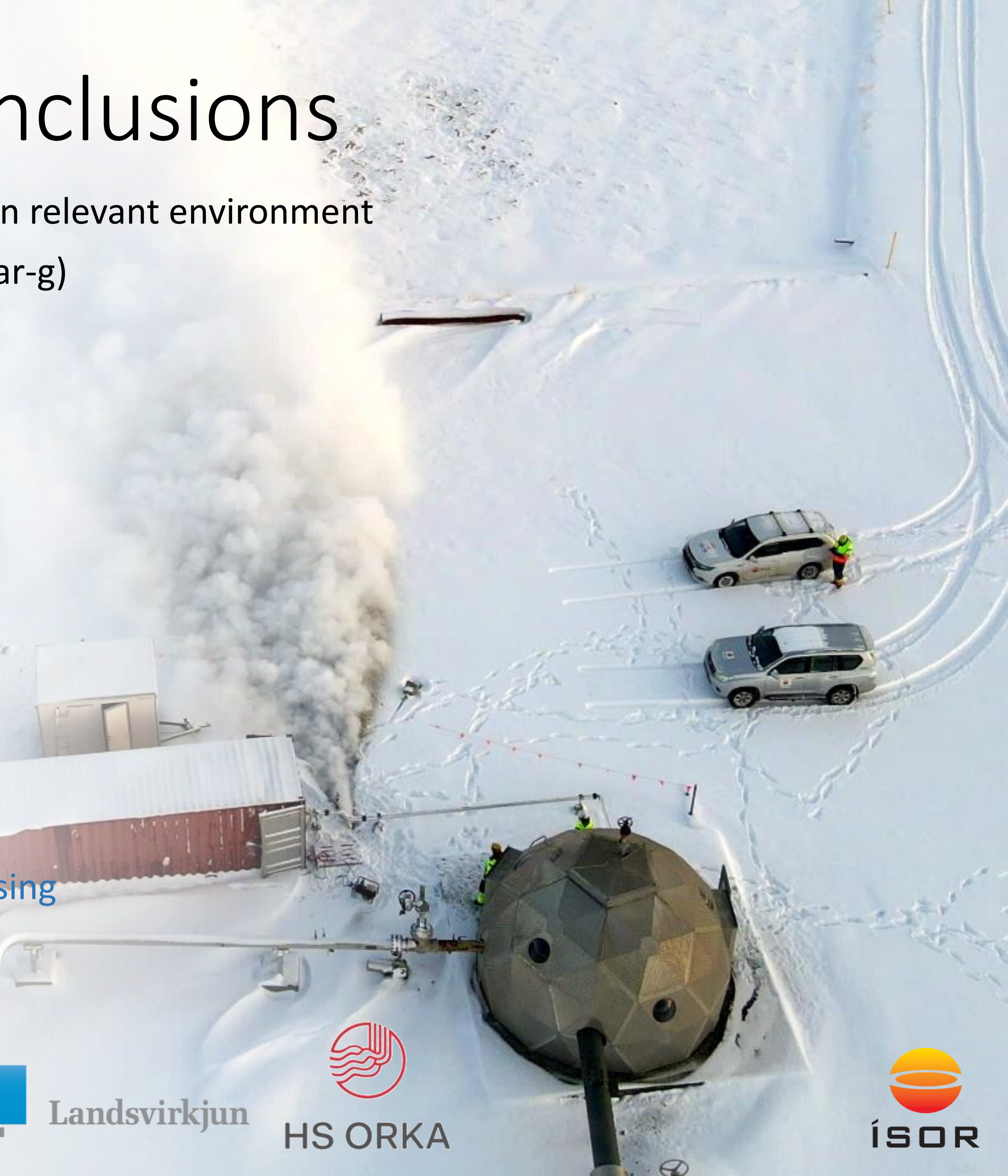
GeConnect Experiment Conclusions

- The main objective was to test function of Flexible Couplings in relevant environment
- Tested with steam from high-temperature well (262°C at 60 bar-g)
- The test confirmed the following:
  - ✓ Casing constrained by cement can slide in cement when it thermally expands
  - ✓ The function of Flexible Couplings has been confirmed in relevant HT environment, by:
    - ✓ Closure of the FC when the casing thermally expands
    - ✓ Opening again when the casing cools down again
  - ✓ Repeatability of closure/opening was confirmed by going through five thermal cycles
  - ✓ By using FC, axial strain is limited as displacement occurs, resulting in stress level well under yield strength of the casing



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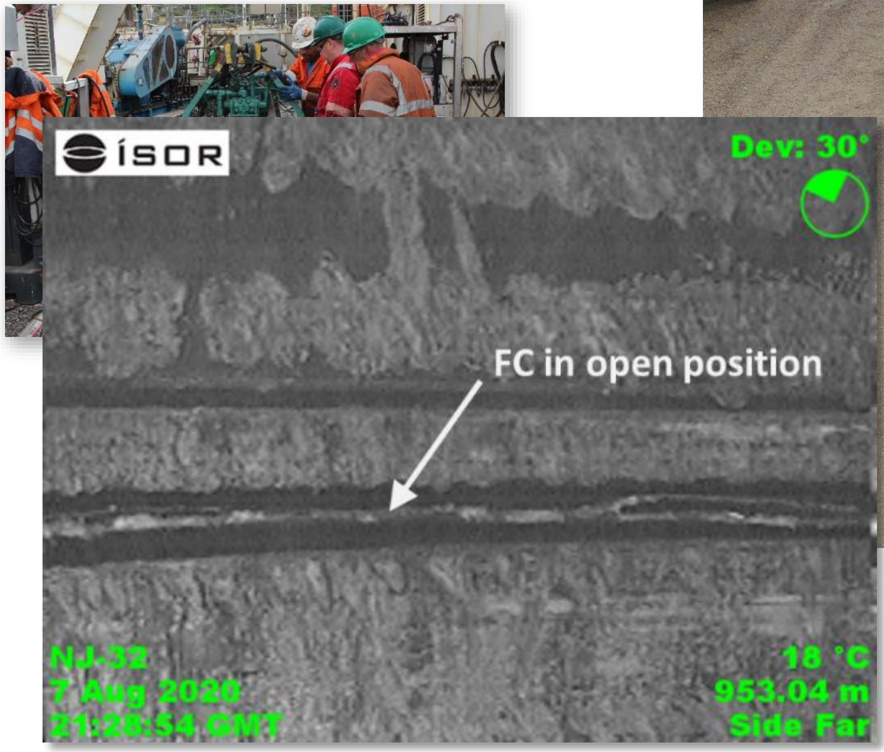
Flexible couplings – run in hole 2020

- Flexible couplings were field tested for the first time in the summer of 2020 in well NJ-32 at Nesjavellir, Iceland geothermal field operated by ON Power
- Difficulties in breaking-out (removing) original BTC casing couplings, so only one FC was eventually run in hole and sits at 950 m depth

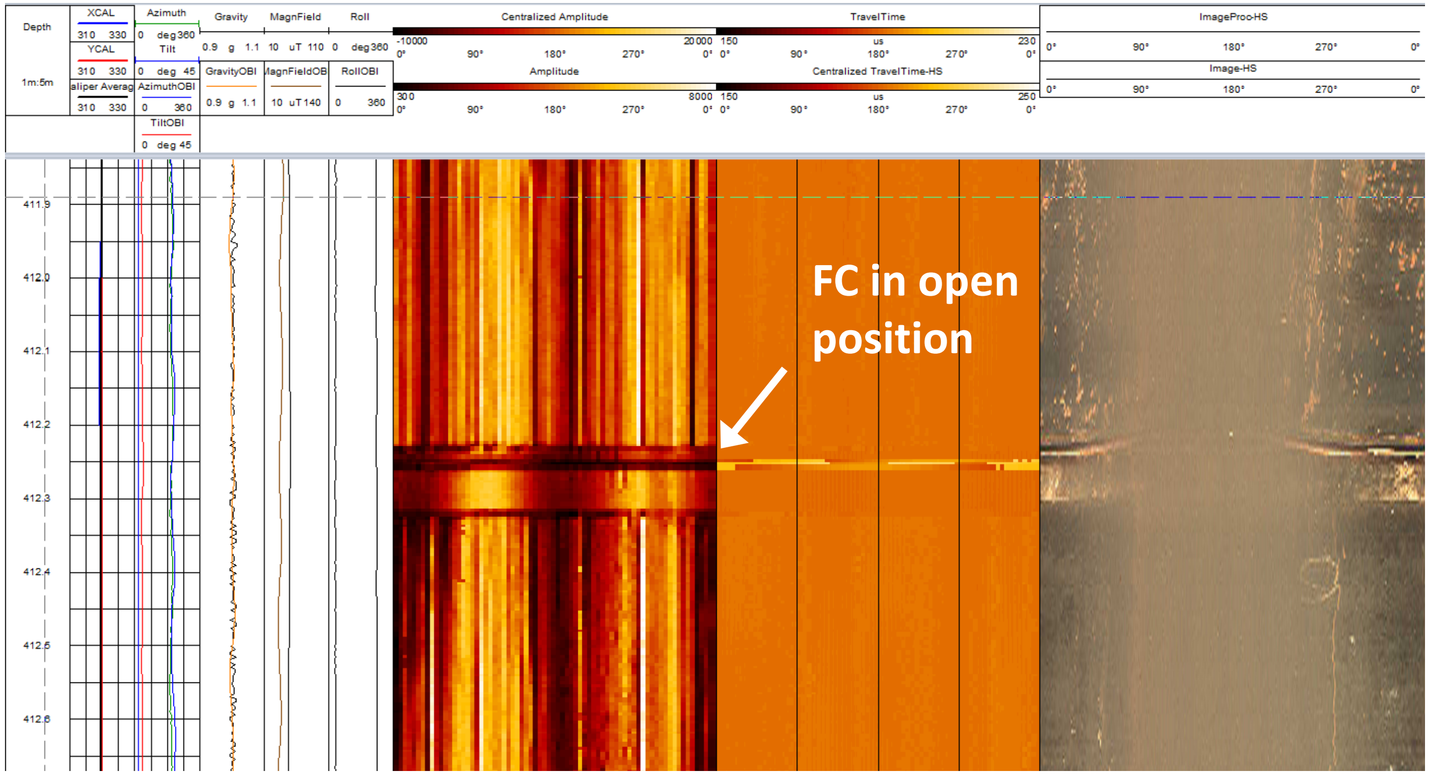


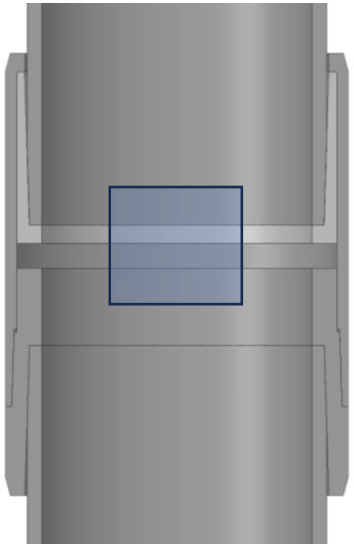
Flexible couplings – run in hole 2025

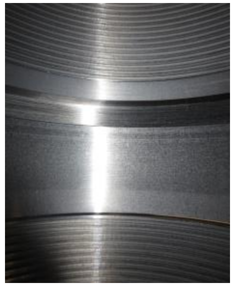
Iceland Drilling's 200 ton rig "Óðinn" (Drillmec HH-220) on site in Nesjavellir, Iceland (300 Mwe and 120 MWth ~1640 L/s hot water)

Flexible couplings – run in hole 2025

- Flexible couplings were successfully installed in a new production well NJ-37 in February 2025 at Nesjavellir, Iceland geothermal field operated by ON Power
- The well is currently being drilled (TD 2000 mMD to >300°C)







Structural testing of Flexible Couplings in DEEPLIGHT

ÍSOR's Flexible Coupling (FC)

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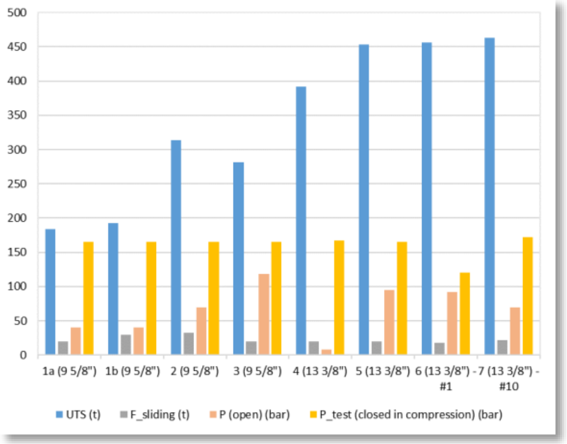
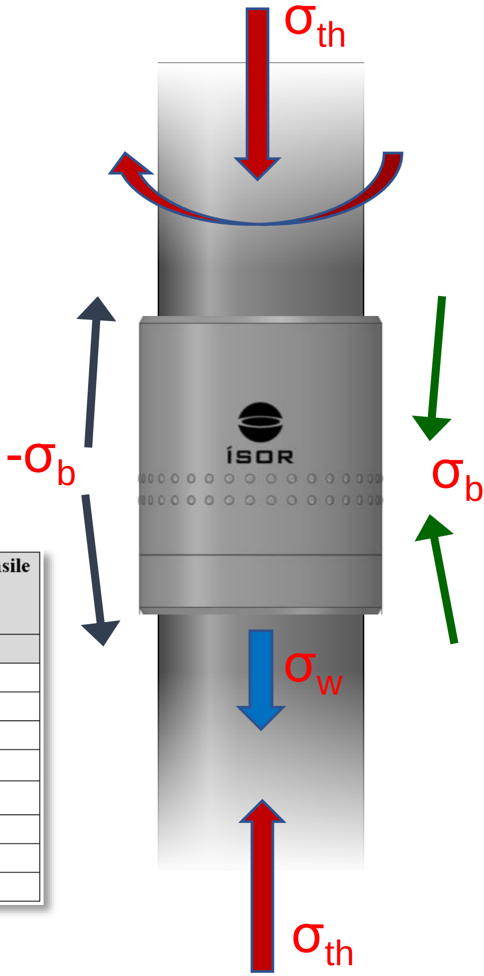
Carry out representative test for Flexible Coupling (ISOR) at ambient temperatures in relation to operational loads of drilling with casing with EPP

- Already established from prototype testing:
  - Compression/tension
  - Closing/opening – sliding force established
  - Ultimate tensile capacity – max hookload established
  - With and without dogleg 2.5 - 5°/30m
  - At relevant conditions >200°C
- Additional testing in DEEPLIGHT:
  - 9 5/8" FC prototype for testing
  - Torque load capacity testing
    - Min make-up: 1.290 daNm / 9.500 lb.ft
    - Max make-up: 2.600 daNm / 19.200 lb.ft
    - IDC's rig Thor capacity (Bentec Euro Rig 350): 7.058 daNm / 52.000 lb.ft
    - FC to be pressure tested with torque, then it will be torqued to failure



Prototype:	Start force	Sliding force	2.5° bending: Sliding force	5° bending: Sliding force	Ultimate tensile load
	(kN)	(kN)	(kN)	(kN)	(kN)
1 – 9 ⅝"	200	200	200	200	1837
2 – 9 ⅝"	300	300	300	300	1926
3 – 9 ⅝"	320	320	320	320	3135
4 – 9 ⅝"	247	176-219	- not tested -	- not tested -	3032
5 – 13 ⅜"	267	189-229	- not tested -	- not tested -	3922
6 – 13 ⅜"	228	196	- not tested -	- not tested -	4452
7 – 13 ⅜"	173	173-177	- not tested -	- not tested -	4429
8 – 13 ⅜"	221	170-200	- not tested -	- not tested -	4580



Deep Light

Novel concepts to construct cost effective geothermal wells with Electro Pulse Power Technology

DeepLight

Teşekkürler!

Takk fyrir!

Bedankt!

Thank you for your attention

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