GEOTHERMICA

GRE GEO

Rijksdienst voor Ondernemend Nederland

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesministerium
für Wirtschaft
und Energie

DER GEOTHERMIE KONGRESS 19.10.2023

DEVELOPMENT OF CORROSION-RESISTANT CASING SYSTEM

AGENDA

1. Greeting, introduction GRE-GEO member and speakers.
2. GRE/GEO project introduction (Ferid Seyidov)
3. Well Design & Installation tools. (Ferid Seyidov)
4. Code compliance. API 5C5 / ISO 13679, CAL, Connections (Javier Holzmann)
5. Composite tubular design envelop. (Kees Rookus)
6. Cementing composite tubulars. Wear of composite tubulars. (Javier Holzmann)
7. Case studies. (Hermen Veltkamp)
8. Discussion & Wrap-up.

DER GEOTHERMIEKONGRESS -OCTOBER 2023, ESSEN, GERMANY

M.SC. FERID SEYIDOV, VULCAN ENERGY ENGINEERING

PROJECT INFORMATION AND WELLS DESIGN

PROJECT CONSORTIUM MEMBERS

GRE GEO

NRG

FPi FUTURE PIPE INDUSTRIES

DYNAFLOW RESEARCH GROUP.

DrillTec

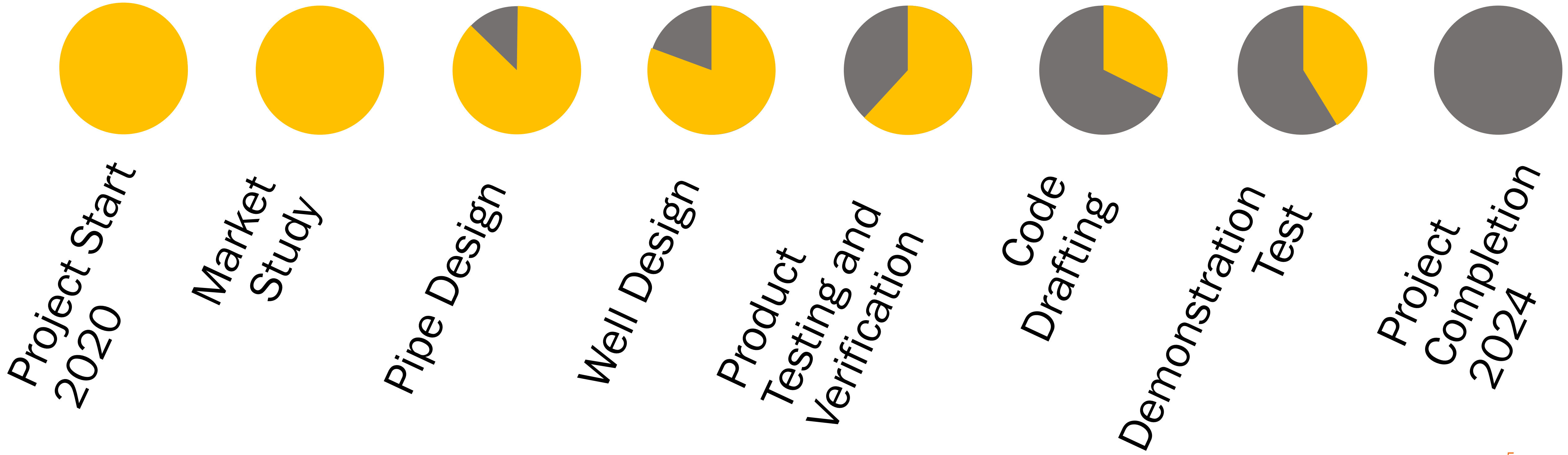
VULCAN ENERGY ENGINEERING

TU Clausthal

SIG

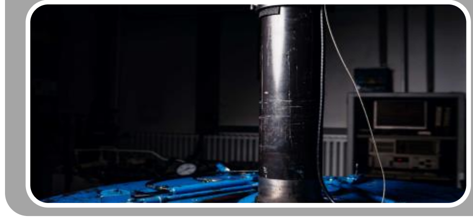
Eartha AG

PROJECT OBJECTIVES



PROJECT GOALS

Development of glass-fibre-epoxy Casing System for the low enthalpy geothermal applications (max 95 °C)



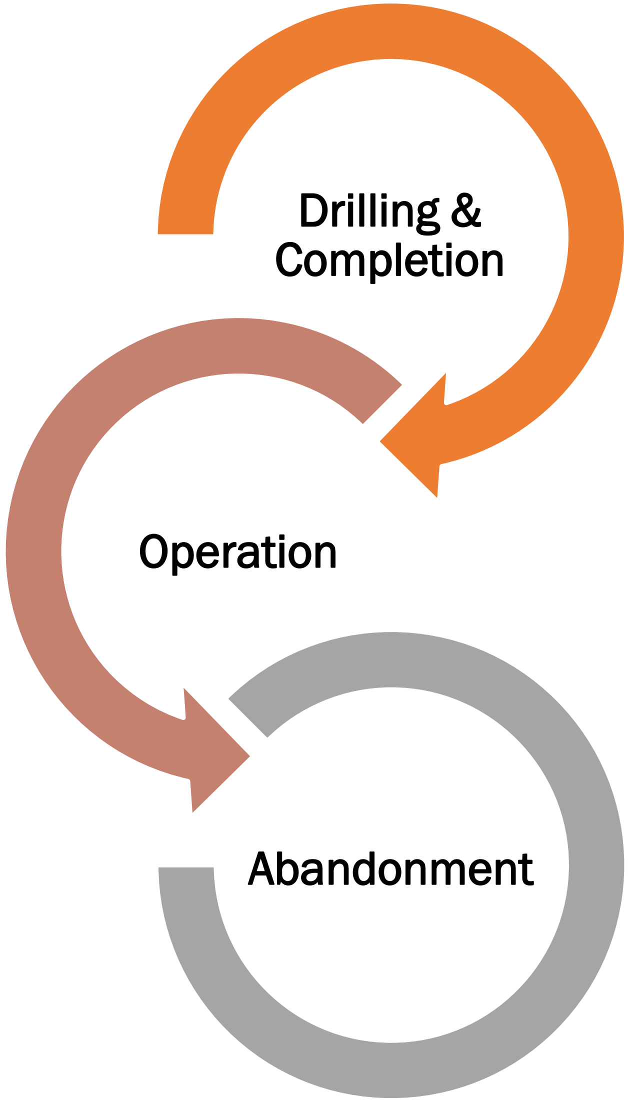
Verify the system integrity against all acting loads with the geothermal well

Development of a suitable Handling and Installation Tools

Development of Guidelines and Norms for for the design and qualification of the GRE piping system

LIFECYCLE ASSESSMENT

- Before proceeding to R&D phase, a well casing lifecycle analysis was performed.
- The structure of LCA was then extended and used for HAZID study.
- The results of HAZID served to identify critical HSE topics and became a guide to both design, operation and test programs



WELL INTEGRITY STUDY

- Was based on Dutch WIS
- Risks were Divided by Phases:
  - Basis of design
  - Design Phase
  - Drilling Phase
  - Operational Phase
  - Intervention (Workover) Phase
  - Abandoning Phase

Consequence						*Increasing Probability*				
Severity Rating	*People*	*Environment*	*Assets*	*Reputation*	*Social*	*A*	*B*	*C*	*D*	*E*
						10^{-6} to 10^{-4} occurrence / year	10^{-4} to 10^{-3} occurrence / year	10^{-3} to 10^{-1} occurrence / year	10^{-1} to 1 occurrence / year	> 1 occurrence / year
						Rare occurrence	Unlikely occurrence	Credible occurrence	Probable occurrence	Likely occurrence
						Never heard of in the Global industry	Heard of in the Global industry	Incident has occurred in DAGO	Happens several times per year in DAGO	Happens several times per year in DAGO
1	No/negligible health effect/injury	No effect	No damage	No impact	No impact					
2	Minor/Slight health effect/injury	Slight effect	Slight damage	Slight impact	Local impact		Manage for continuous improvement			
3	Major health effect/injury	Localised effect	Localized damage	Considerable impact	Regional impact			Incorporate risk reduction measures		
4	Permanent disability/up to 3 fatalities	Major effect	Major damage	National impact	National impact				Intolerable	
5	More than 3 fatalities	Massive effect	Extensive damage	International impact	International impact					

X	Not GRE specific, but worthwhile to be noted as point of attention also for GRE
X	GRE specific action required
?	Flagged as important, but requires follow up/further assessment
!	Flagged as critical/Action required

WELL INTEGRITY STUDY

RISK MITIGATION ACTIONS

- Tools
- Design
- Control
- Standards/Guidelines
- Training
- Testing/Experience

GRE Speci	HAZARD NUMB	HAZARD	SCENAR	Column1	GRE SPECIFIC2	Action matrix							
y	Item	Description	Sub item	Description		Tools	Design	Control	Standard	Guidelines	Training	Testing	CHECK
y													
	16	Corrosive substances											
n	16,1	Brine		See 14.1 (Toxic fluid, brine)									
y	16,2	Well stimulation fluids and descaling		Aggressive to health if incorrectly selected, contained, managed. Potential damage to the well equipment	GRE moderate compatible with HCl (typically up to 20%, check) GRE not compatible with HF				X	X		?	!
n	16,3	CO2		Enhanced corrosion due to presence of O02 See 14.1.1 (Toxic fluids)									
y	16,4	H2S		Materials which require specialist selection not used resulting in cracking of well components	GRE in general applied in oil/gas wells with H2S. Check max. levels of H2S in Dutch regions. If GRE is compatible with H2S levels than n/a.				X	X		?	!
y	16,5	Chloride (Cl)		Chloride in shallow formations causing enhanced degradation of cement and reduced barrier integrity	Not GRE specifc. N/A.								
	17	Biological Hazards											
y	17,1	Water borne bacteria	17.1.1	Potential for microbially inluenced corrosion	Compatibility with GRE: Check by literature review.				X	X		?	!
y			17.1.2	Potential to increase the scaling risk (e.g. to the action of sulphate reducing bacteria SRB). See 15.2.1 (Toxic solids, scale formation)	Stagnant conditions might be an issue? Risk is considered to be low.				X	X		?	!

The results of HAZID Study will be available to the Public by Geothermica

MARKET RESEARCH

In order to define the generalized well design an extensive market study was performed.

<u>Results Summary</u>

- **Most common Casing Sizes**: 13 3/8" and 9 5/8"
- **Surface Casing Sizes:** 28" - 18 5/8"
- **Older wells have smaller Diameters**
- **Average depth**: 2359 m TVD
- **Common Well Architecture**:
  1 Conductor, 2 Casings and 2 Liners.

Well Name		Total Depth	Conductor	Top	Bottom	Casing1	Top	Bottom	Casing2	Top	Bottom
CAL-GT-03		2977	22	0	27	13 3/8	0	858 mMD			
HAG-GT-01	Deviated	2702 m AHD (RKB)				13 3/8	0	252 AHD (m)	10 3/4	0	1238.3 AHD (m)
HAG-GT-02	Deviated	2330 m AHD (RKB)				13 3/8	0	250 AHD (m)	10 3/4	0	1188 AHD (m)
BRI-GT-02	Deviated	2216.31 m Rotary Table									
CAL-GT-02	Deviated	1694 m AHD	22	0	27	13 3/8	0	906.5 mMD			
PNA-GT-02	Deviated	2860m AH				14	0 mAH	72 mAH	9 5/8	978 mAH	2369 mAH
PNA-GT-04	Deviated	2957 mAH				14	0 mAH	78 mAH	9 5/8	0 mAH	1169 mAH
HLH-GT-02	Vertical	695.5 mAH	18 5/8	0	30	13 3/8	0 m	160.3 m	9 5/8	0 m	653.2 m
VDB-GT-02-S1	Deviated	2332 mAH	23	0	51	13 3/8	0 mAH	532 mAH	9 5/8	384 mAH	1497 mAH
VDB-GT-04	Deviated	2006 mAH	18 5/8	0 mMD	60 mMD	9 5/8	0 mMD	906 mMD			
HEK-GT-02	Deviated	2954.2 m MDBRT	20	0 mAH	84 mAH	13 3/8	0 mAH	1407 mAH	9 5/8	1307 mAH	2393 mAH
HON-GT-01-S2	Deviated	2615 mMD				9 5/8	0 mMD	1103 mMD			
KKP-GT-02	Deviated	2205 mAH RT	14	0	100	9 5/8	0 mAH	1113 mAH	7	1051 mAH	2067 mAH
LIR-GT-02	Deviated	2880 m MD	24	0 mMD	140 mMD	13 3/8	0 mMD	1125 mMD			
MDM-GT-02-S2	Deviated	2589 m MD	28	0 mMD	93 mMD	18 5/8	0 mMD	531 mMD	13 3/8	0 mMD	1317 mMD
MDM-GT-03	Deviated	2686 mMD	28	0 mMD	88 mMD	18 5/8	0 mMD	532 mMD	13 3/8	0 mMD	1401 mMD

Sources: 1) NLog Data
2) Stakeholder survey

PRODUCT DIAMETER SELECTION

Boundary values:

- Aimed drift diameter: 17,59” – 18,94”
- Maximal casing diameter : 16”
- Optimal casing diameter : 13 3/8” – 14”
- GRE casing OD – will be optimized and defined during tests.

William Lyons, Norton J. Lapeyrousse, in Formulas and Calculations for Drilling, Production, and Workover (Third Edition), 2012

Goals reminder:

- Primary Goal: Development of a casing string.
- Secondary Goal: Development of a production string (inner string or tubing).

CASING SYSTEM

Surface Casing

- Conventional C-Steel: 26-22″

Production Casing

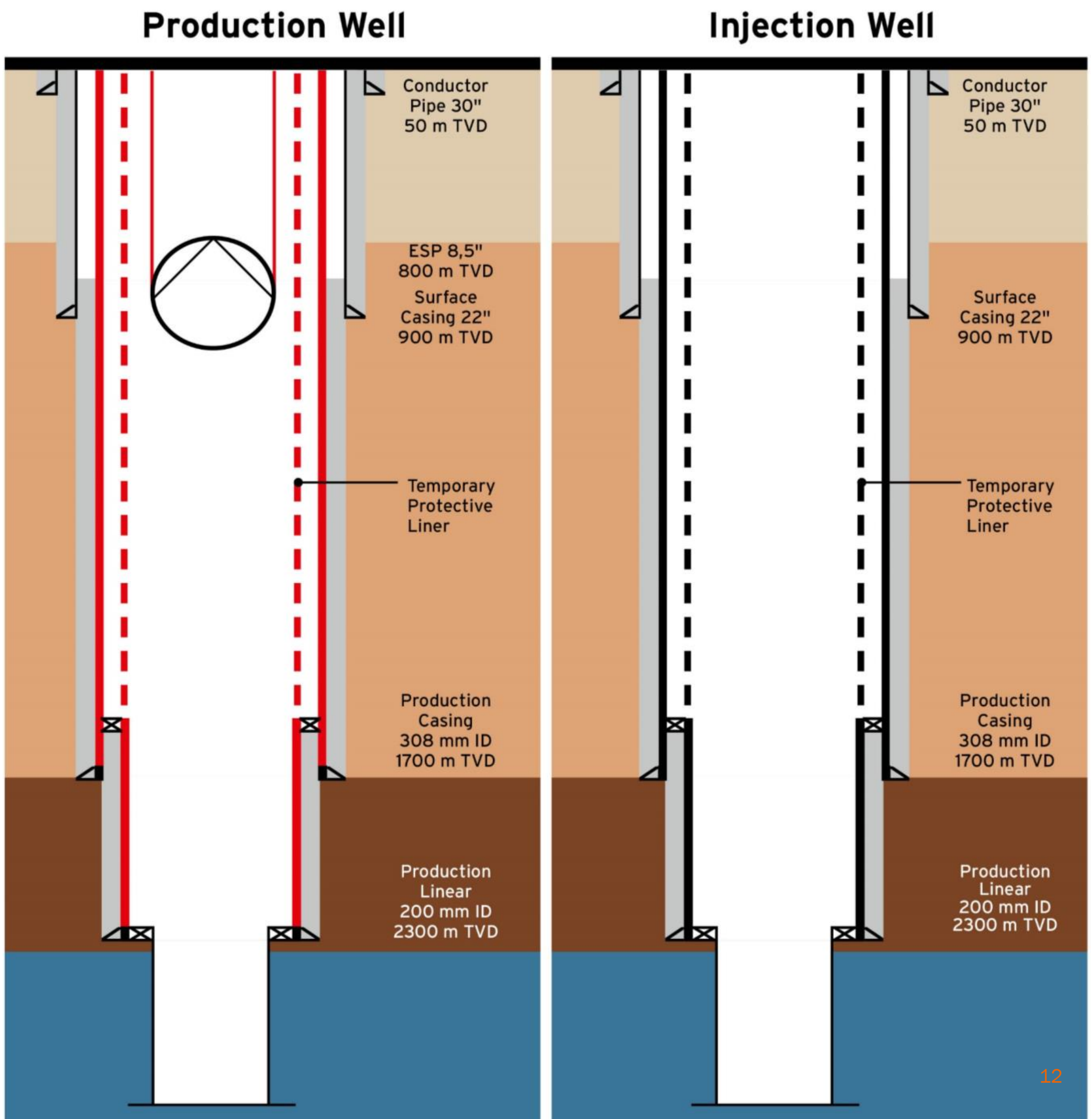
- Replacement for conventional: 13 3/8″ – 14″
- Maximal casing ID : 308 mm or 12 1/8″
- GRE casing OD : 17 ½″

Production Liner

- Replacement for conventional: 9 5/8″
- Maximal casing ID : 200 mm
- GRE casing OD : 11 1/10″
- Drift Diameter : 7 ¾″ or 196,85 mm

Follow up Options

- Conventional piping OD: 6 1/8″



GRE LINER DESIGN

Designed to install in already existing wells, the **protective liner** will provide an ample protection against corrosion and significantly reduce scaling.

Casing String

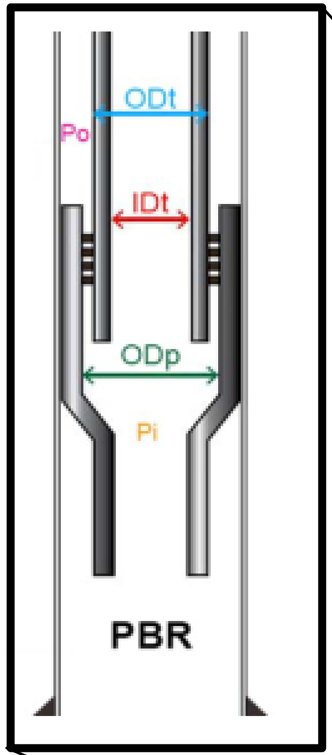
Conventional C-Steel: 20-18 5/8”

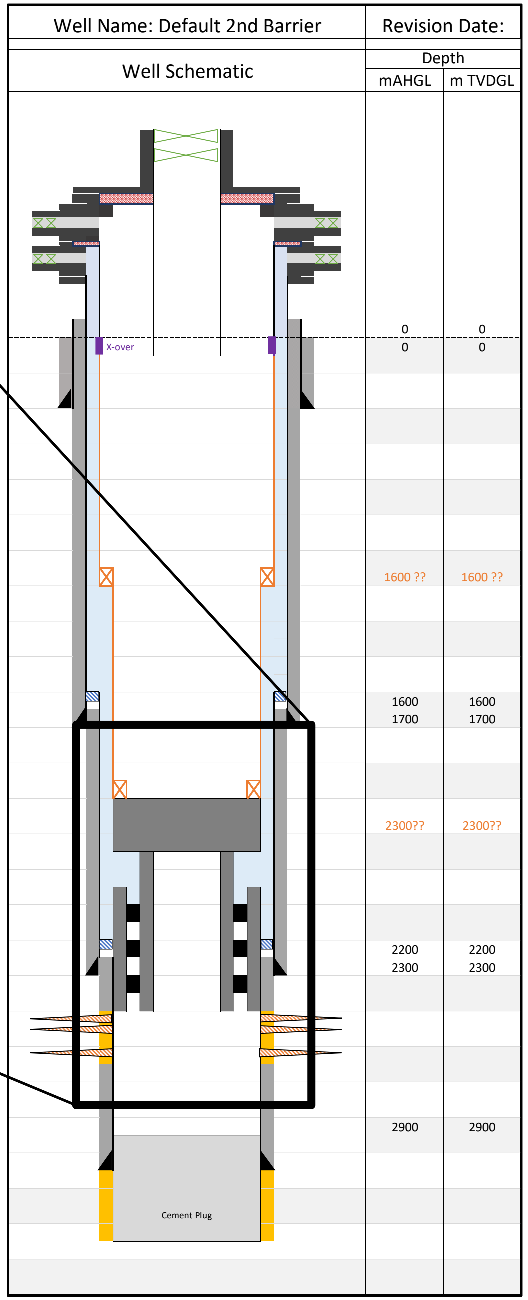
Conventional C-Steel: 13 3/8” – 14”

Followed by C-Steel: 9 5/8” Liner

Liner: 7”

Covered by GRE Liner

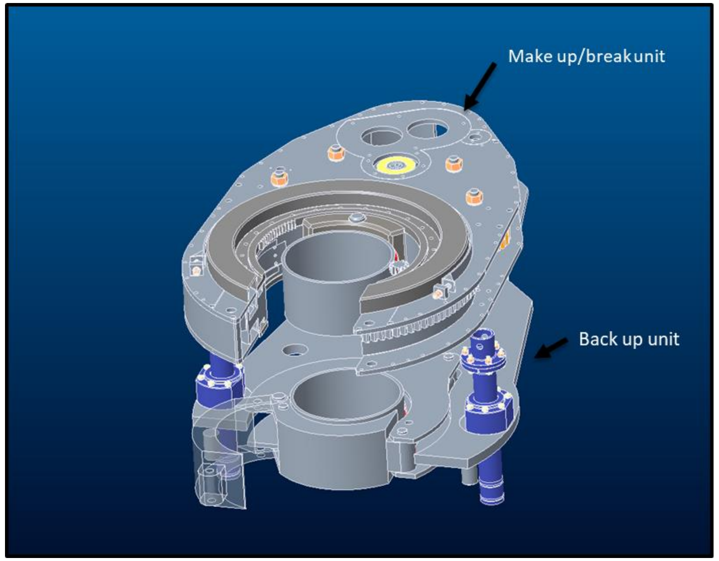


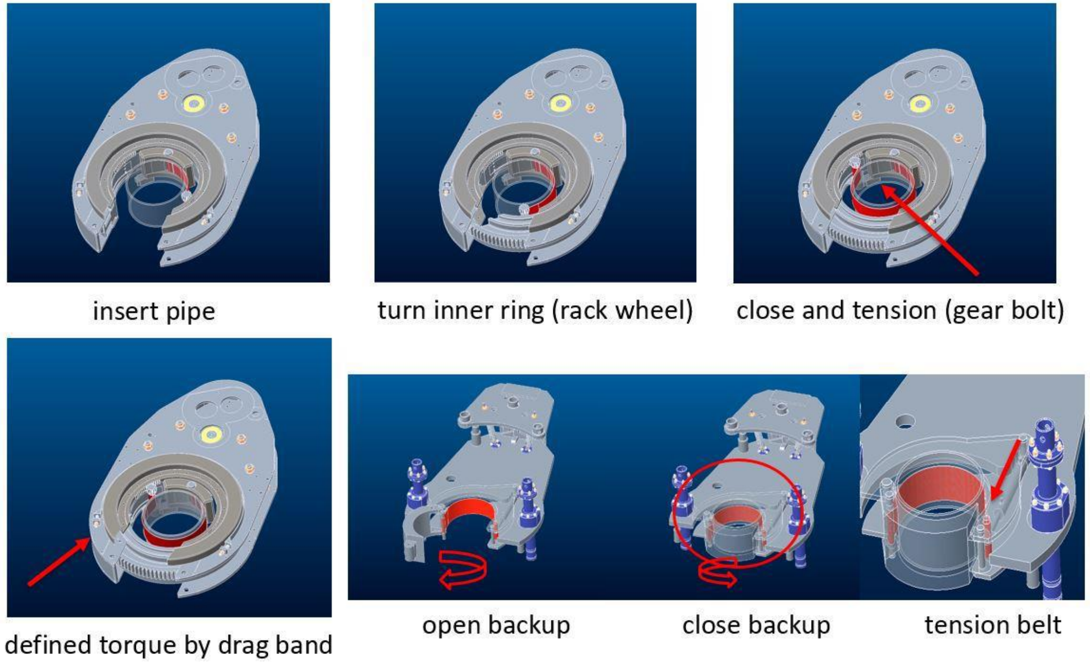


BELT TONG: MAKE-UP/BREAK-OUT UNIT

Status

- Advantages
  - Full automation possible.
  - Drag/Friction between pipe and belt adjustable.
  - Design of belt quite flexible (lot of types on market).
  - Torque adjustable.
  - Change in diameter can be adjusted with gear bolt end point.
- Disadvantages
  - Friction dependent on surface condition of pipe.
  - Friction cannot infinitely increase by continuous belt tensioning.
  - May need different inserts for diameter ranges.
  - Break connections with same set up still to be confirmed (only low break-out torque possible).





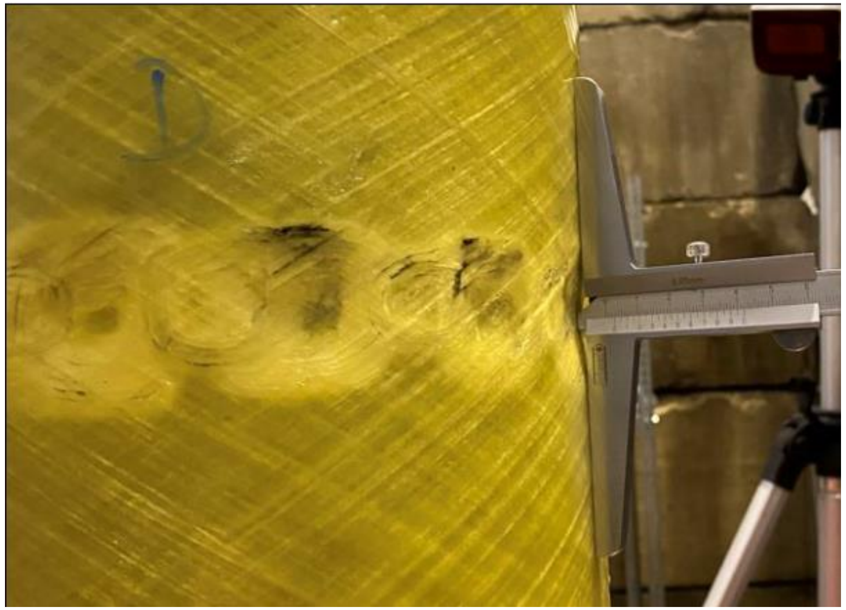
Working sequence

TEST WITH ANNULAR BOP

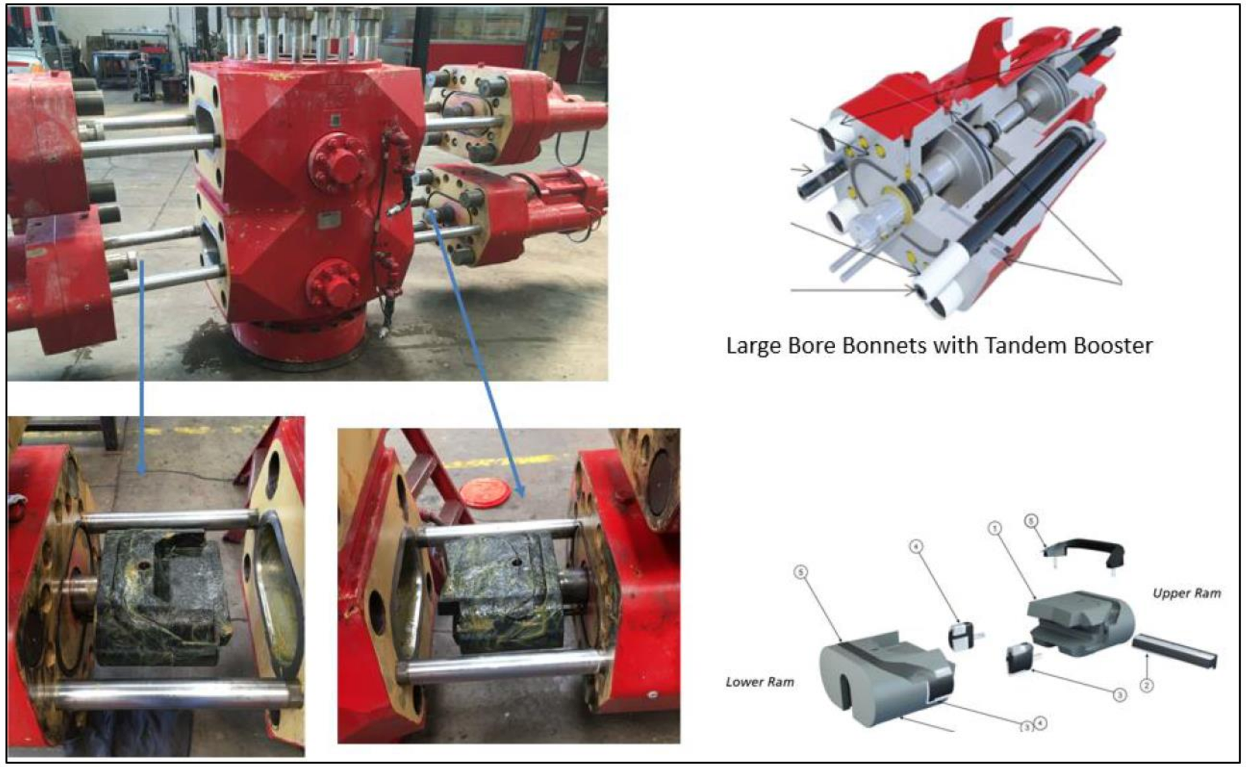
Test Program

- Impact of Annular BOP (Blowout Preventer) Closing Pressure – **1500 psi or 104 bars**
- Combination of closing pressure with applied wellbore pressure - **1500 psi or 104 bars**
- Evaluate the sealing and durability characteristics of GRE-pipe under Annular BOP Pressure test conditions - **Success**
- Annular function test – closing pressure & wellbore pressure with GRE-pipe - **Success**

In all tests GRE could perform in identical conditions to API Steel Casings.



TEST WITH SHEAR RAM BOP



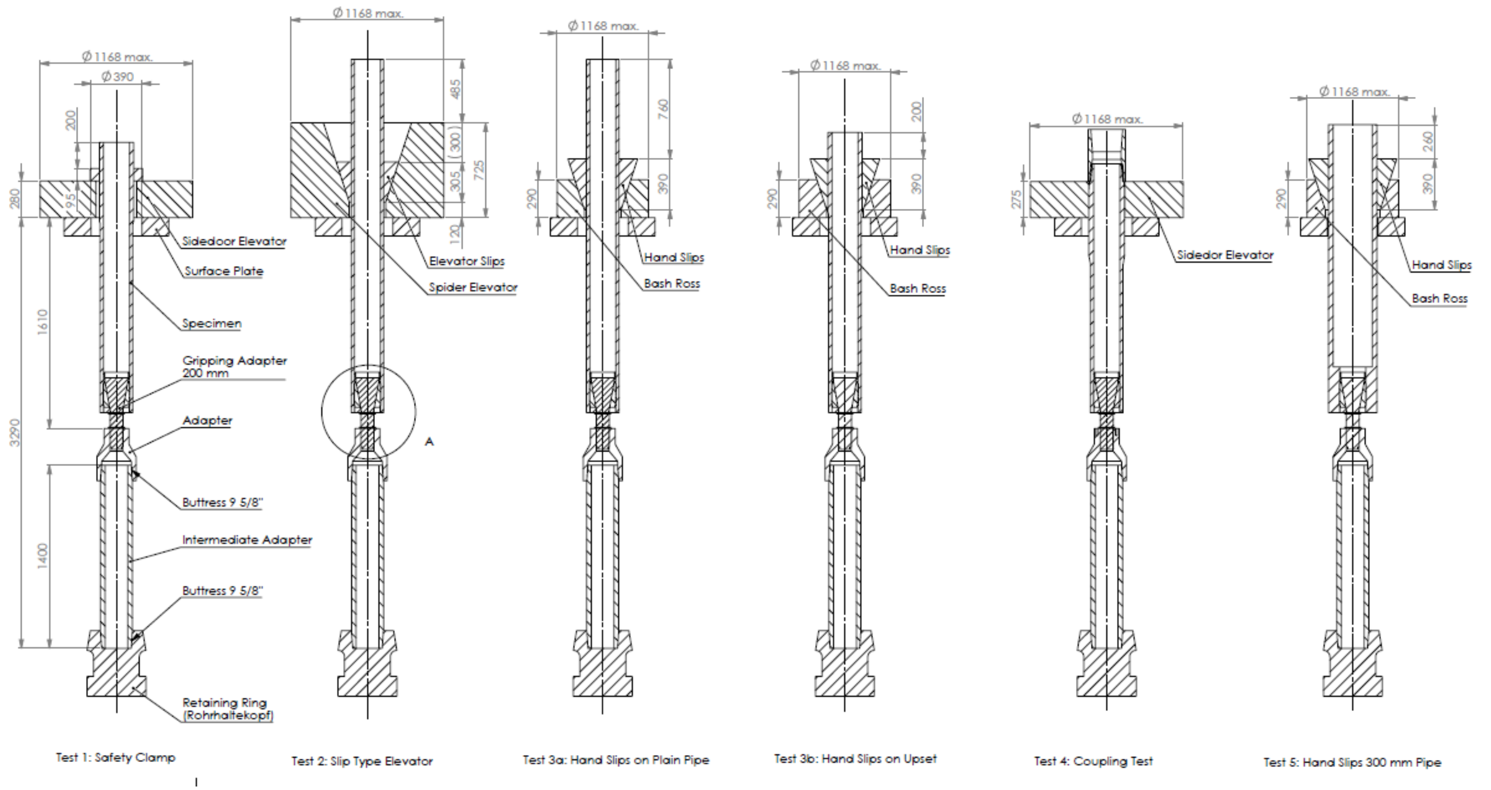
Size	*13-5/8"*	BOP type	*U-type Double Ram, upper cavity: Standard bore; lower: Large Bore Bonnets with Tandem Boosters*
Pressure Rate	*10.000 psi*	OEM/CEM	*Cameron / Streicher (SDT)*

20 bar and 690 bar test performed successfully after pipe was sheared without functionality disruptions

HANDLING TOOLS TESTING

In order to check the compatibility of the pipe and connector system a series of test are planned

- Safety Clamp
- Slip Type Elevator
- Hand and Slip
- Coupler Test



Question and Answer

VULCAN ENERGY ENGINEERING

GEOTHERMICA

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DER GEOTHERMIEKONGRESS -OCTOBER 2023, ESSEN, GERMANY

DR. JAVIER HOLZMANN, TU-CLAUSTHAL

CODE COMPLIANCE - API 5C5 / ISO 13679

CODE COMPLIANCE – API 5C5 / ISO 13679

1. Introduction
2. API 5C5 description
3. Gas tightness
4. Connection assessment level (CAL)
5. Low enthalpy CAL

INTRODUCTION

- SOURCE:

  All tables and schemes used in this presentation were taken from the API 5C5 standard

- NAME:

  API 5C5 “Procedures for Testing Casing and Tubing Connections”

- ORIGIN:

  Developed based on improvement to the old API 5C5, proprietary test procedures (i.e. Shell) and input from leading users and consultants around the world

- SCOPE:

  The aim of this standard is to validate the connection test load envelope and failure limit loads.

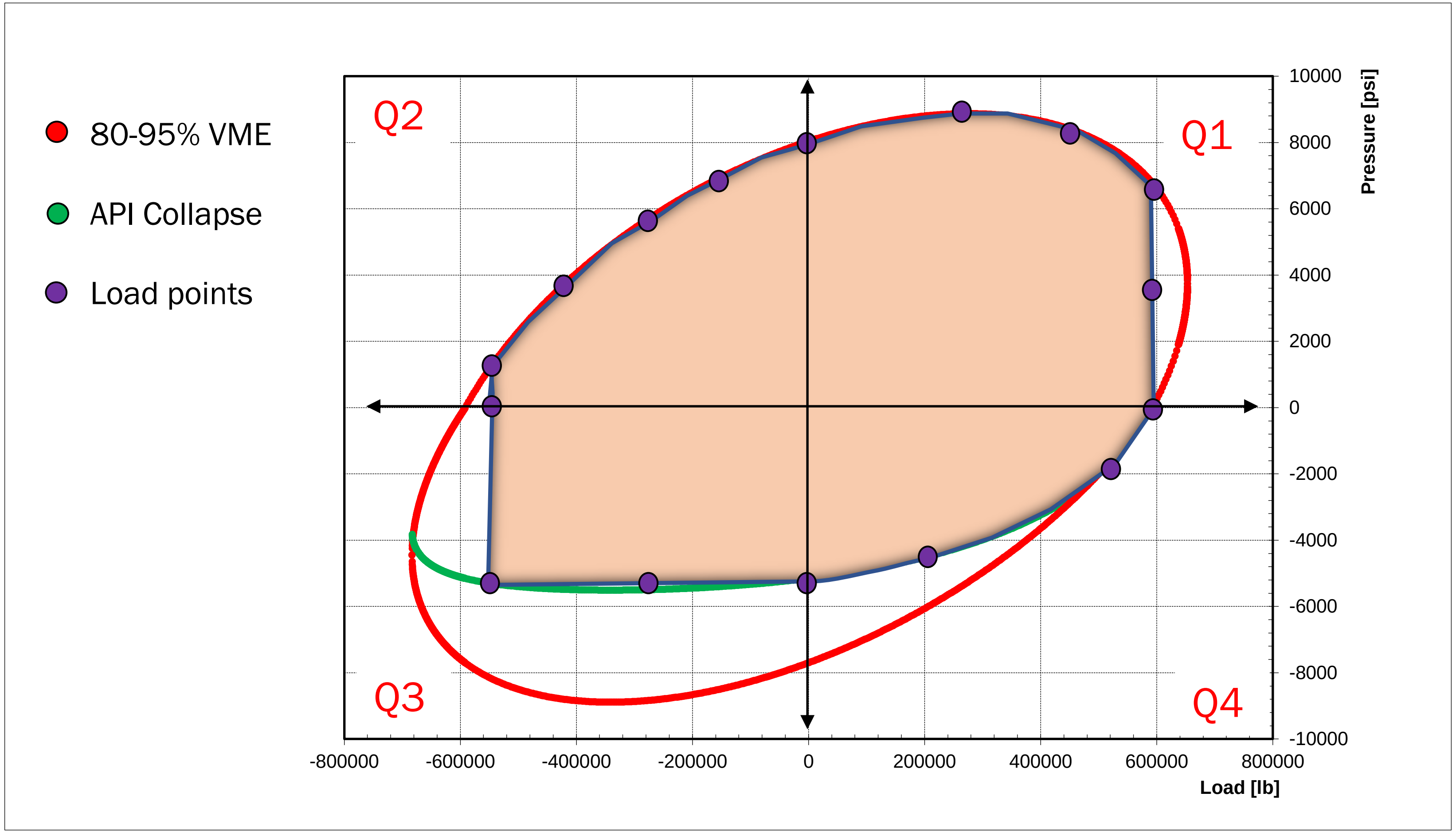
- WHY?

  Although pipe body test and limit loads are well understood in general, the same cannot be stated for the connection(in general different and often less than the pipe body). Consequently experimental validation is required.

API 5C5 – MAIN ASPECTS

- Establishes the **minimum design verification** testing **procedures** and acceptance criteria (covers most commonly encountered well conditions).
- Everything is based on **pipe body** and **yield strength** and conditions for **worst case scenario**.
- **Time** is not taken into account, neither loads during the lifetime of the well.
- Practical way **to compare the performance** of different connections.
- **Corrosion and chemical compatibility** are not addressed in this code.
- Definition of connection assessment levels (**CAL**)

CONNECTION ENVELOPE AND QUADRANT DEFINITION



GAS TIGHTNESS

- LEAK DEFINITION:

Passage of test medium outside of the containment space whether in the equipment or the connection.

The average allowable rate is <=0.3 cm3 / 5 minutes and decreasing trend.

- GAS TIGHT CONNECTION:

A connection is gas tight when pass all the selected qualification test program under without leak.

CONNECTION ASSESSMENT LEVEL (CAL)

CAL IV (5 SPECIMENS) - MOST TESTING RIGOR.

- QI-QII-QIII-QIV + Bending + RT & HT.
- The total cumulative hold time 238 hours.
- Extensive thermal loading at an elevated temperature of 180°C.
- Limit load tests in quadrants I, II, and III.

CAL III (5 SPECIMENS) - SIGNIFICANT TESTING RIGOR.

- QI-QII-QIII-QIV + Bending + RT & HT.
- The total cumulative hold time is 185 hours.
- Less severe thermal cycling levels than CAL IV / temperature maintained at 180 °C.
- Limit load tests in quadrants I, II, and III.

CONNECTION ASSESSMENT LEVEL (CAL)

CAL II (3 SPECIMENS) - MODERATE TESTING RIGOR

- QI-QII-QIII-QIV + Bending + RT & HT.
- The total cumulative hold time is 80 hours.
- External pressure only at RT. Elevated temperature limited to 135 °C.
- Limit load tests in quadrants I, III.

CAL I (2 SPECIMENS) - LESS TESTING RIGOR.

- may utilize liquid or gas as an internal pressurization medium.
- QI-QII-QIII-QIV + Bending + RT.
- The total cumulative time is 20 hours.
- External pressure only at RT. No elevated temperature.
- Limit load test in quadrant I.

CAL FOR GRE-GEO (LOW ENTHALPY) ?

- SEALABILITY TEST: **ADHOC Test procedure based on the API 5C5 CAL I - II (CAL II-III from the previous version)** is foreseen (2 samples in all quadrants)

- **Make and Brake (M&B) test**: test procedure, dopes, torque, quantity of M&B to be defined based on the product.

- **Baking** (worst scenario for sealability): can be eliminated for low enthalpy geothermal applications (wet service conditions).

Question and Answer

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GRE GEO

DER GEOTHERMIEKONGRESS - OCTOBER 2023, ESSEN, GERMANY

KEES ROOKUS, FUTURE PIPE INDUSTRIES

SERVICE ENVELOP – GRE COMPOSITE TUBULARS

SERVICE ENVELOP – GRE COMPOSITE TUBULARS


INTERNATIONAL STANDARD

ISO 14692-2

Second edition
2017-08

Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping —

Part 2:
Qualification and manufacture

Industries du pétrole et du gaz naturel — Canalisations en plastique renforcé de verre (PRV) —
Partie 2: Qualification et fabrication

Reference number
ISO 14692-2:2017(E)

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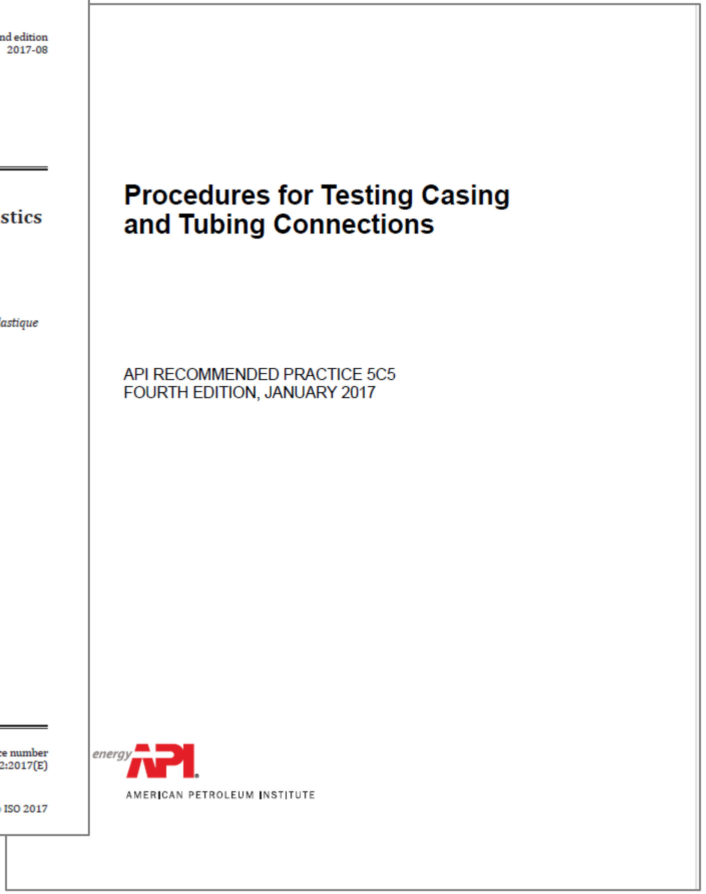
Procedures for Testing Casing and Tubing Connections

API RECOMMENDED PRACTICE 5C5
FOURTH EDITION, JANUARY 2017

energy API
AMERICAN PETROLEUM INSTITUTE

- Code compliance work in GRE/GEO, mainly based on:
  - API 5C5:2017 *'Procedures for Testing Casing and Tubing Connections'*
  - ISO 14692-2:2017 *'Petroleum and natural gas industries – Glass-reinforced plastics (GRP) piping'*

SERVICE ENVELOP – GRE COMPOSITE TUBULARS

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Reference number
ISO 14692-2:2017(E)

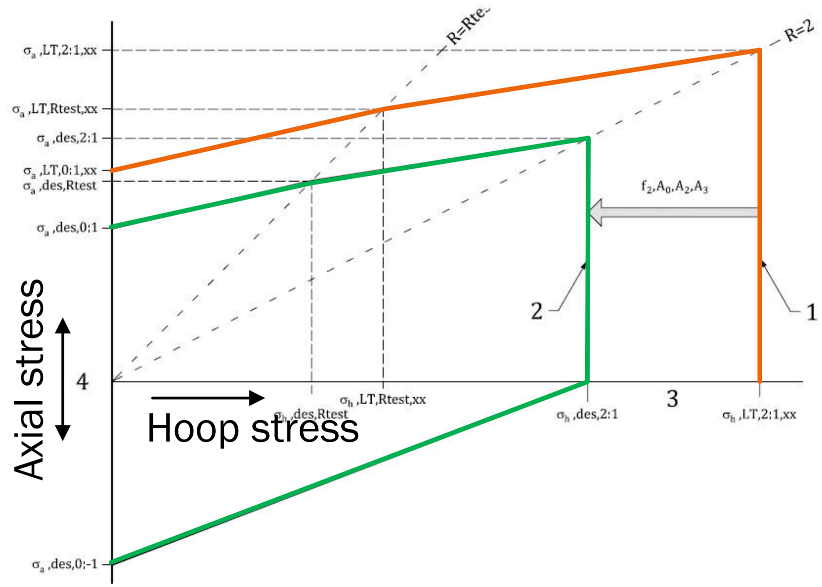
© ISO 2017

- ISO 14692-2:2017 *'Petroleum and natural gas industries – Glass-reinforced plastics (GRP) piping'*
- Well established industry standard.
  - 1994: UKOOA (UK Offshore Operators Association) *'Specification and recommended practice for the use of GRP piping offshore'.*
  - 1998: Shell DEP 31.40.10.19-Gen *'GRP PIPELINES AND PIPING SYSTEMS (AMENDMENTS/SUPPLEMENTS TO UKOOA DOCUMENTS)'.*
  - 2002: ISO 14692:2002: *'Petroleum and natural gas industries – Glass-reinforced plastics (GRP) piping'.*
  - 2017: ISO 14692:2017: *'Petroleum and natural gas industries – Glass-reinforced plastics (GRP) piping'.*

SERVICE ENVELOP – GRE COMPOSITE TUBULARS

ISO 14692

Industry piping notation



Key

1 long term envelope

2 design envelope

Figure 3 — Relationship between the long term envelope(s) and design envelope(s)

- Service envelope (green) based on threshold envelope (orange) and safety factors.
- Threshold envelope: envelope that defines the load levels to avoid incremental damage to the pipe composite.
- ISO 14692: *'The threshold envelope is set equal to the long-term envelop at 65ºC (for GRE)'*.
- For design temperatures above 65ºC: apply temperature reduction factors based on long-term tests at design temperature or higher.
- Maximum design temperature for GRE composite tubulars at 'hot/wet condition' is 100ºC.

SERVICE ENVELOP – GRE COMPOSITE TUBULARS

ISO 14692
Industry piping notation

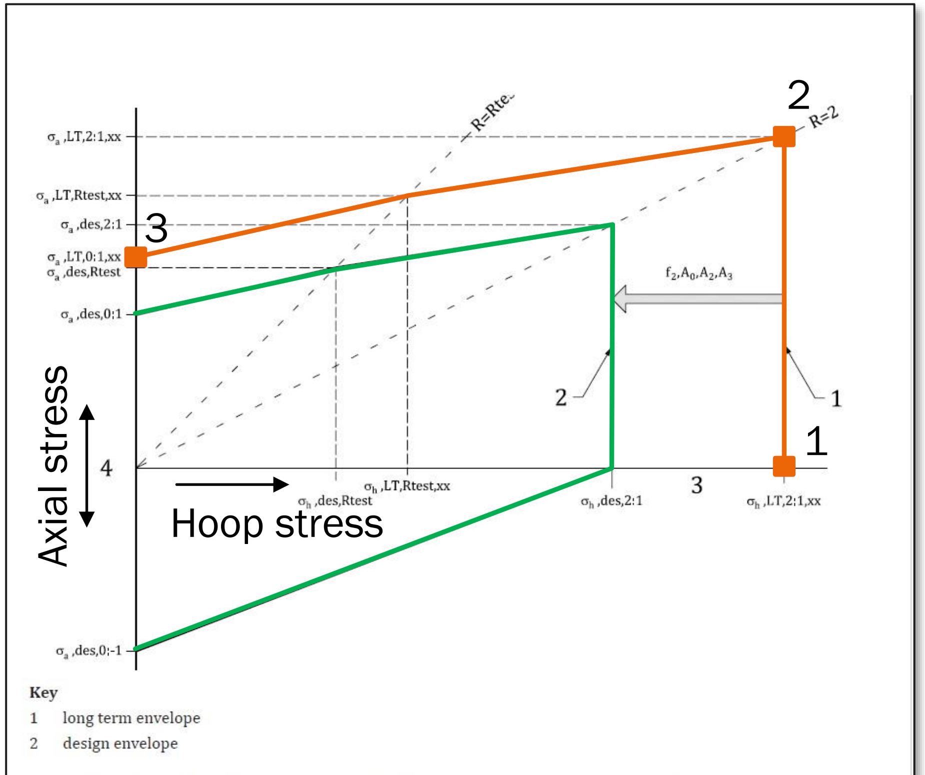
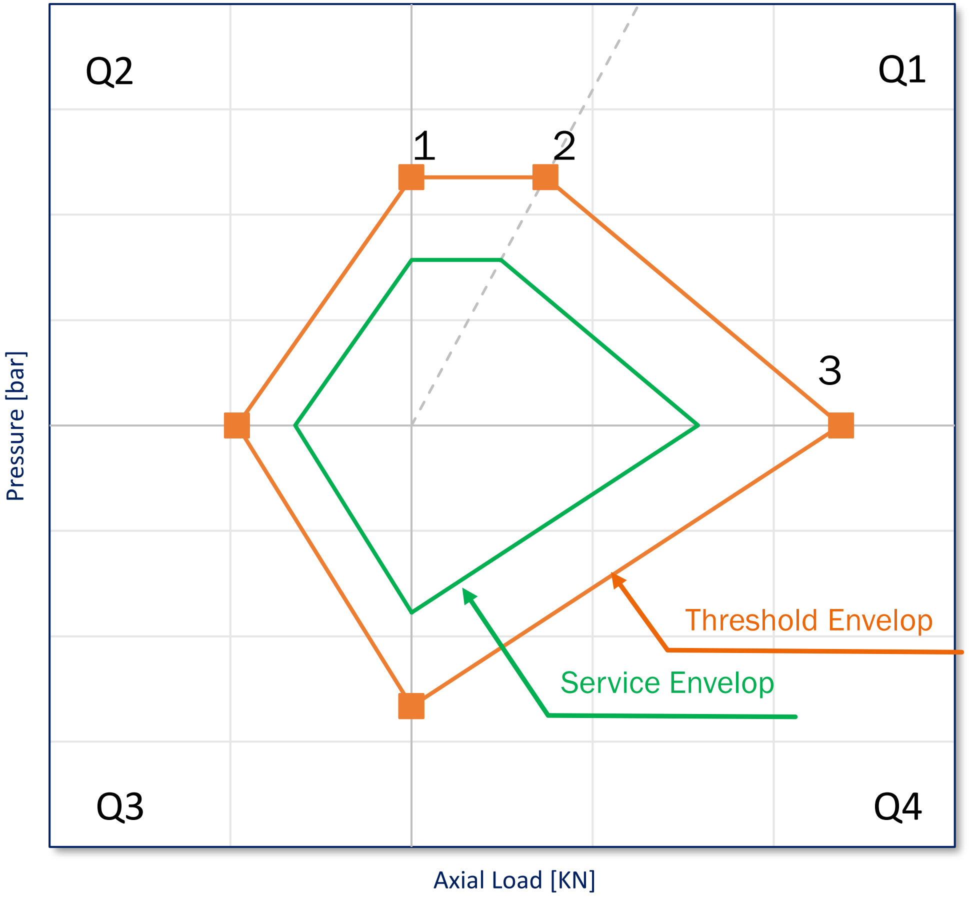
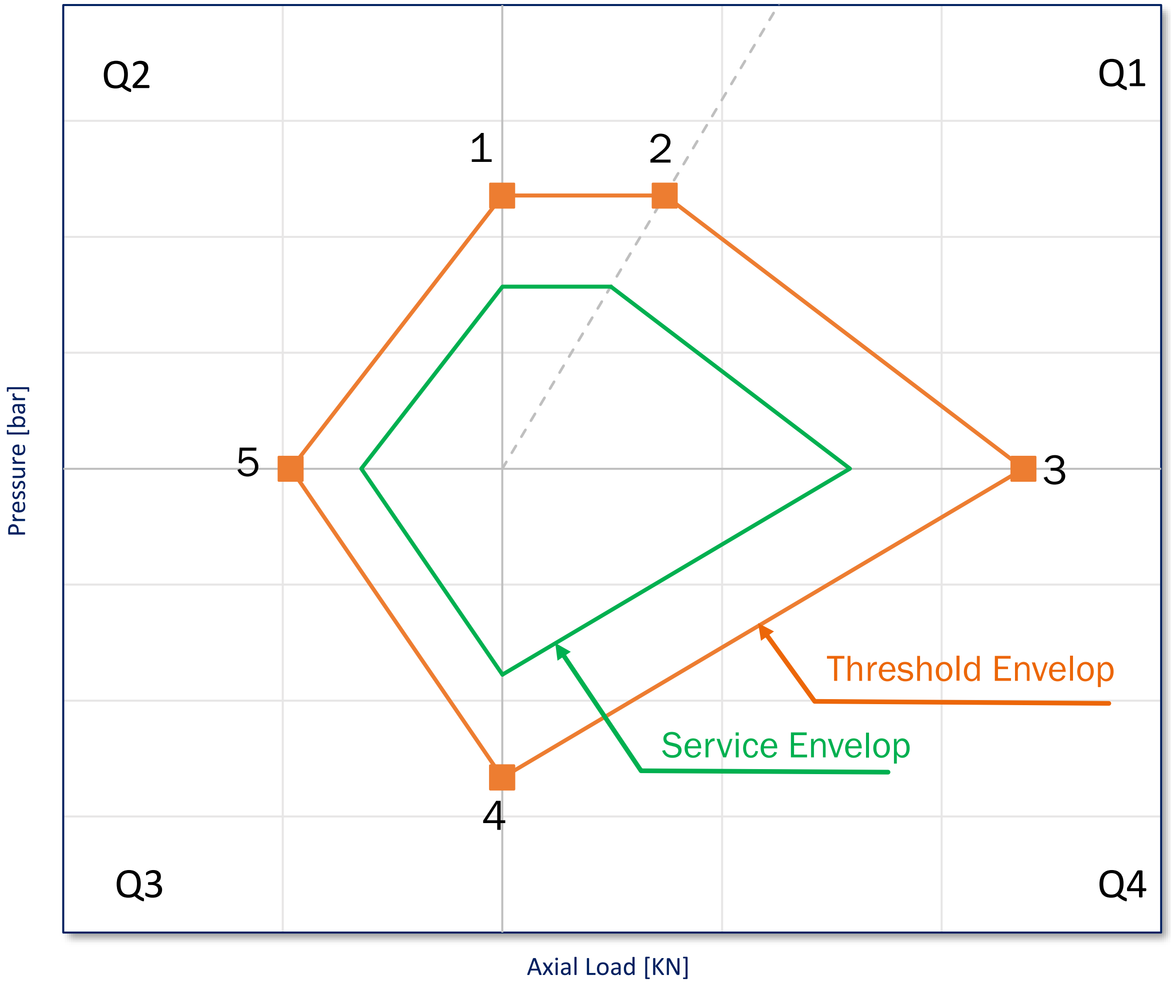


Figure 3 — Relationship between the long term envelope(s) and design envelope(s)

GRE-GEO
Downhole tubular notation



SERVICE ENVELOP – GRE COMPOSITE TUBULARS



- In GRE-GEO, the threshold is verified at 5 load conditions:

  1 – Internal pressure without cap-end loads.

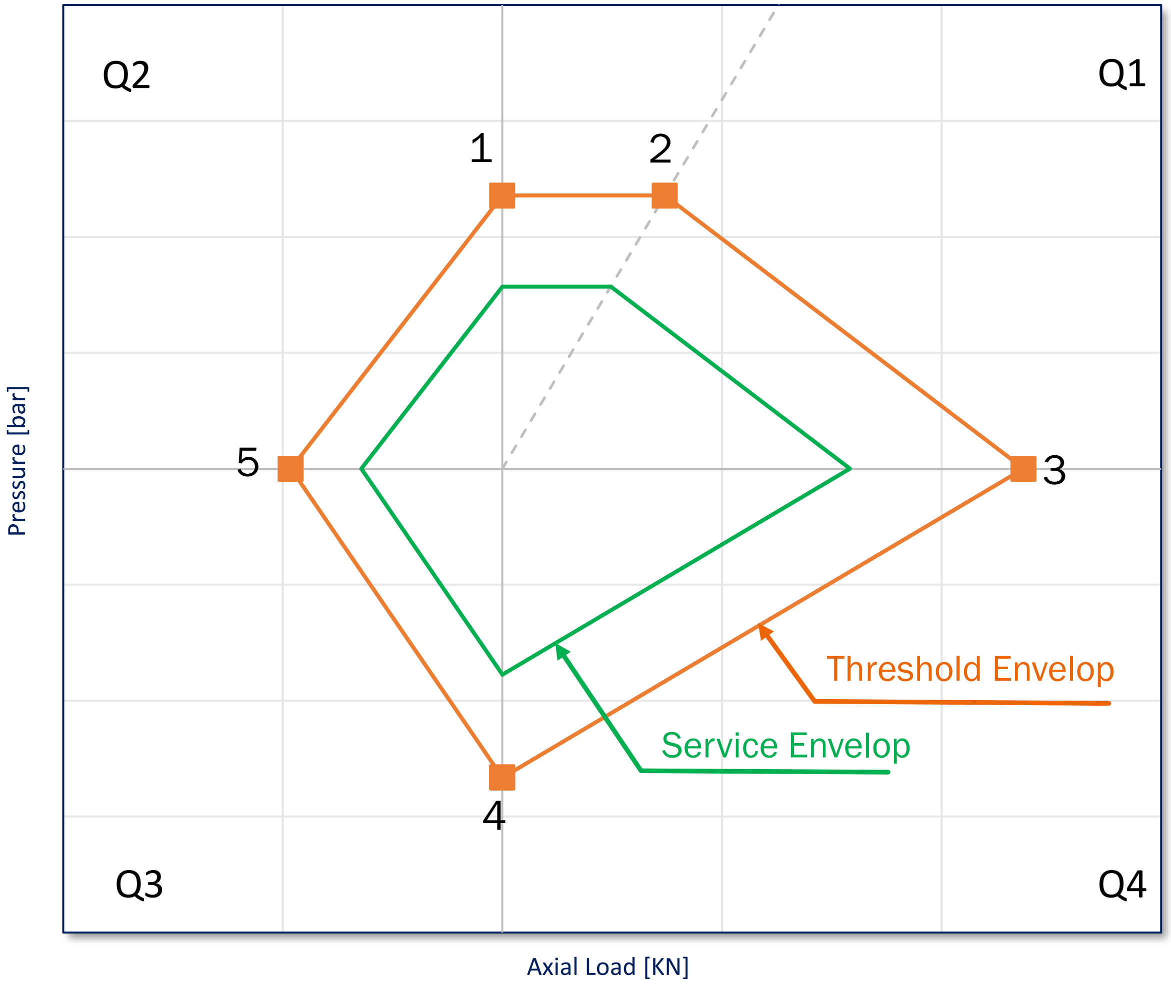
  2 – Internal pressure with cap-end loads.

  3 – Axial tensile load.

  4 – Collapse pressure.

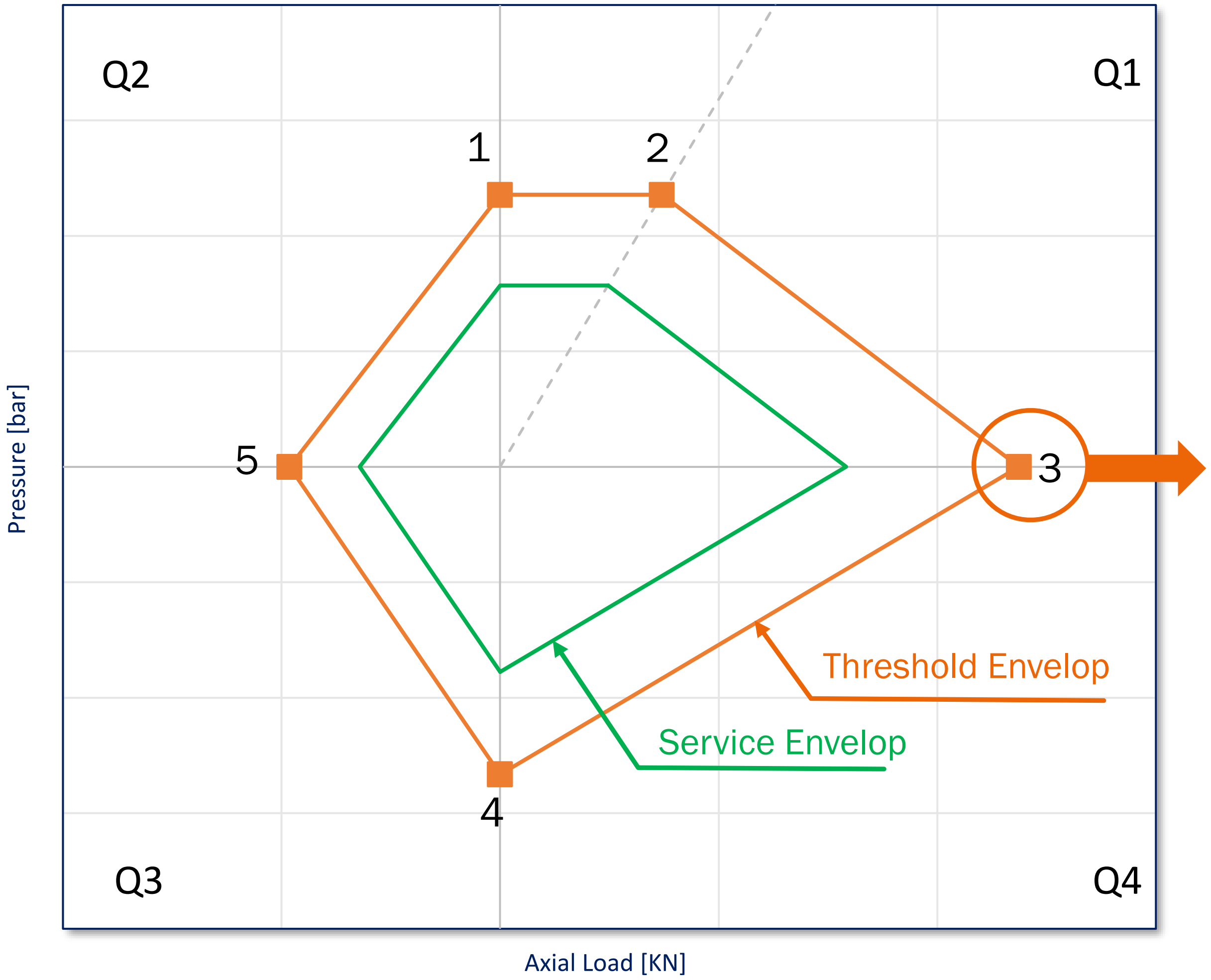
  5 – Axial compressive load.

SERVICE ENVELOP – GRE COMPOSITE TUBULARS

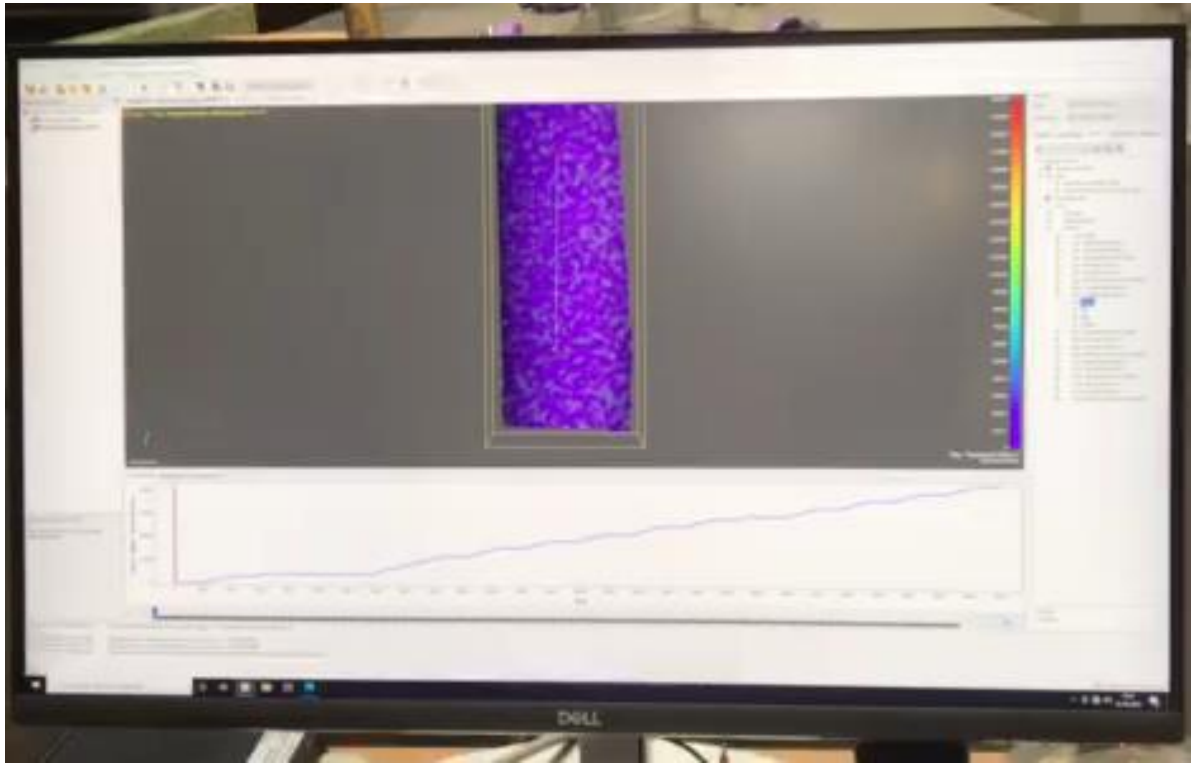


- Performance based Threshold envelop
  - Points 1 and 2 - per ISO 14692.
  - Points 3 and 4 - new test regimes
  - Point 5 - per ASTM *D695 'Standard Test Method for Compressive Properties of Rigid Plastics'* - conservative material factor.

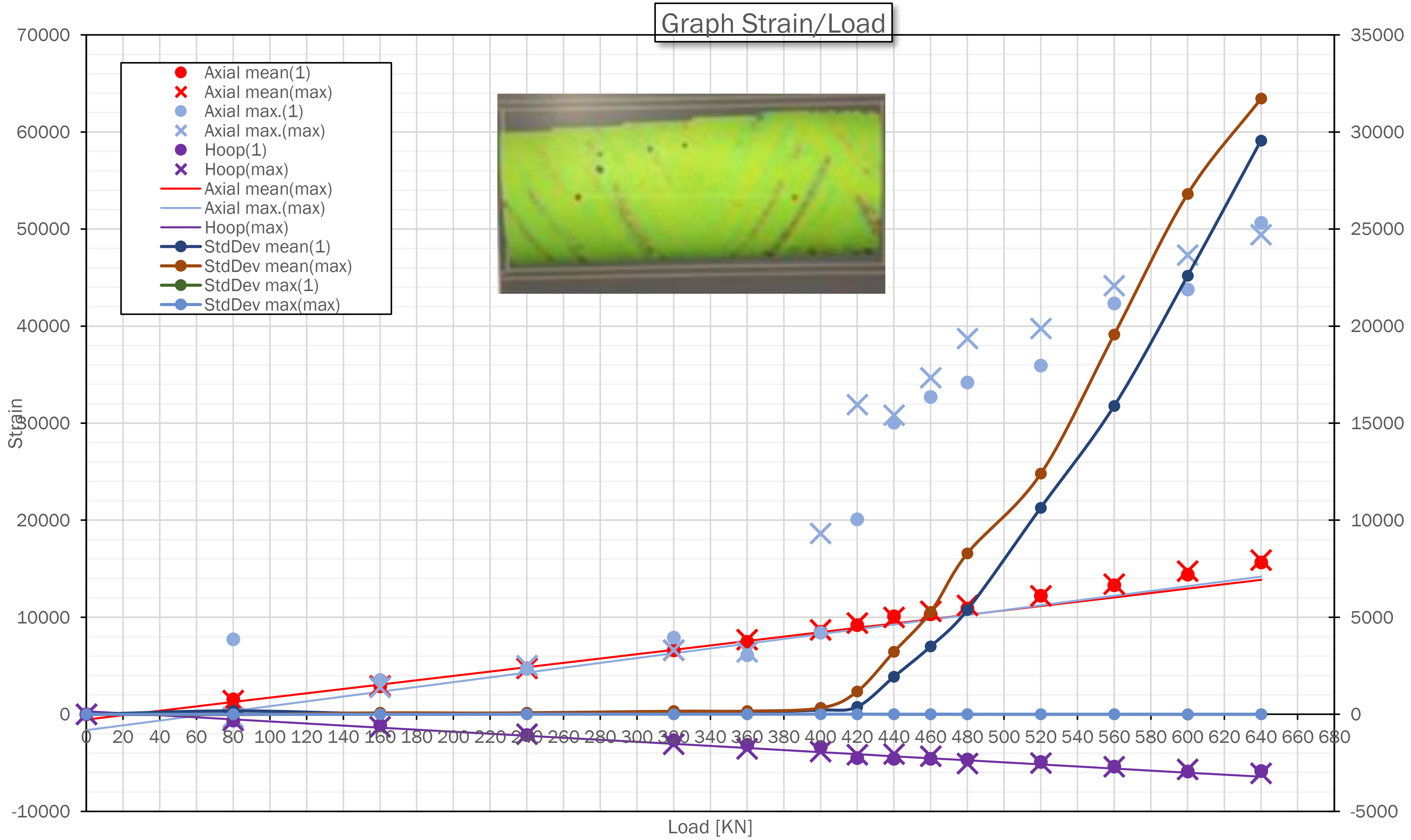
SERVICE ENVELOP – GRE COMPOSITE TUBULARS



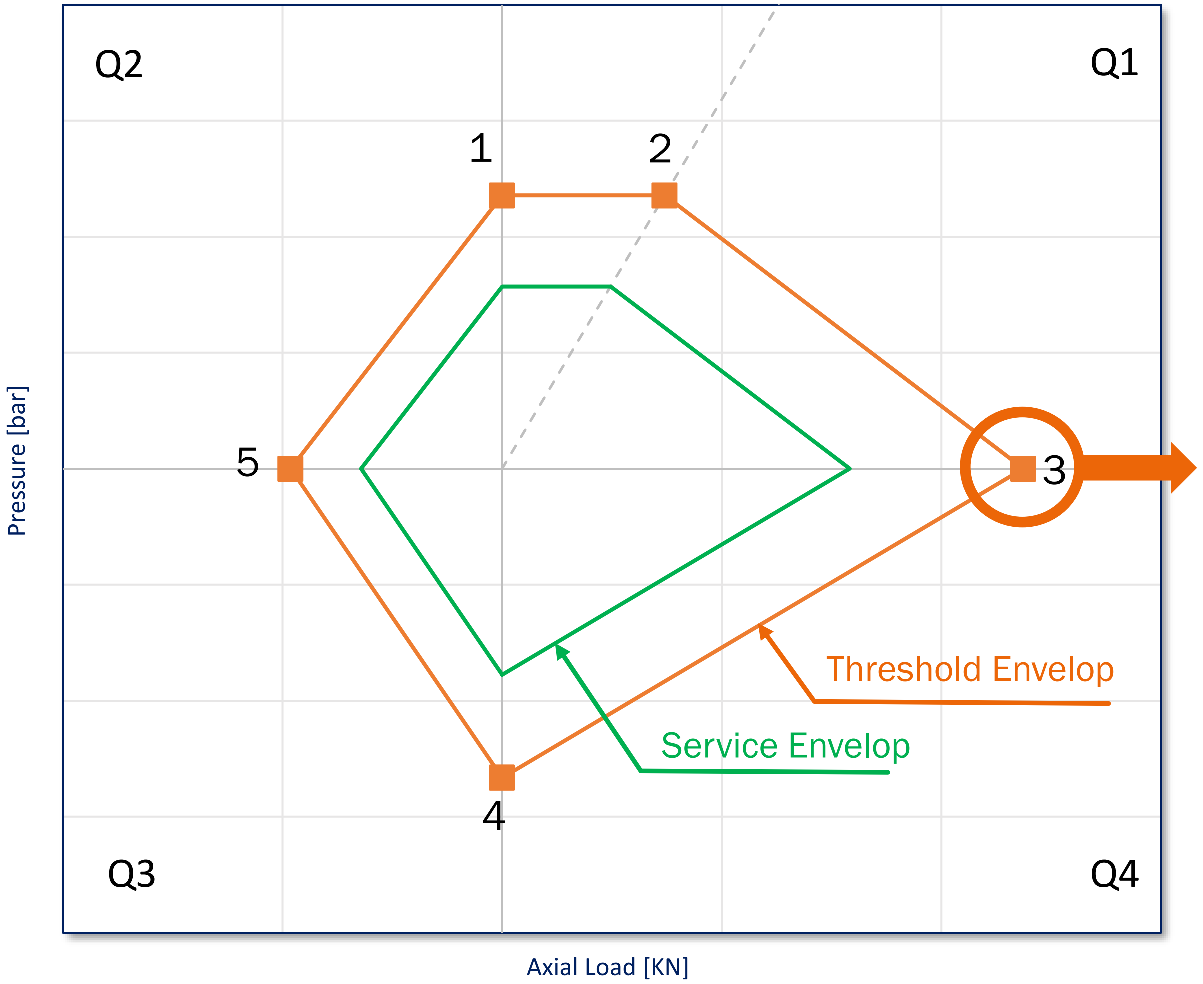
- Threshold – initial test indicating the resistance at onset of crack propagation, by optical strain measurement



SERVICE ENVELOP – DETECTION OF ONSET DAMAGE



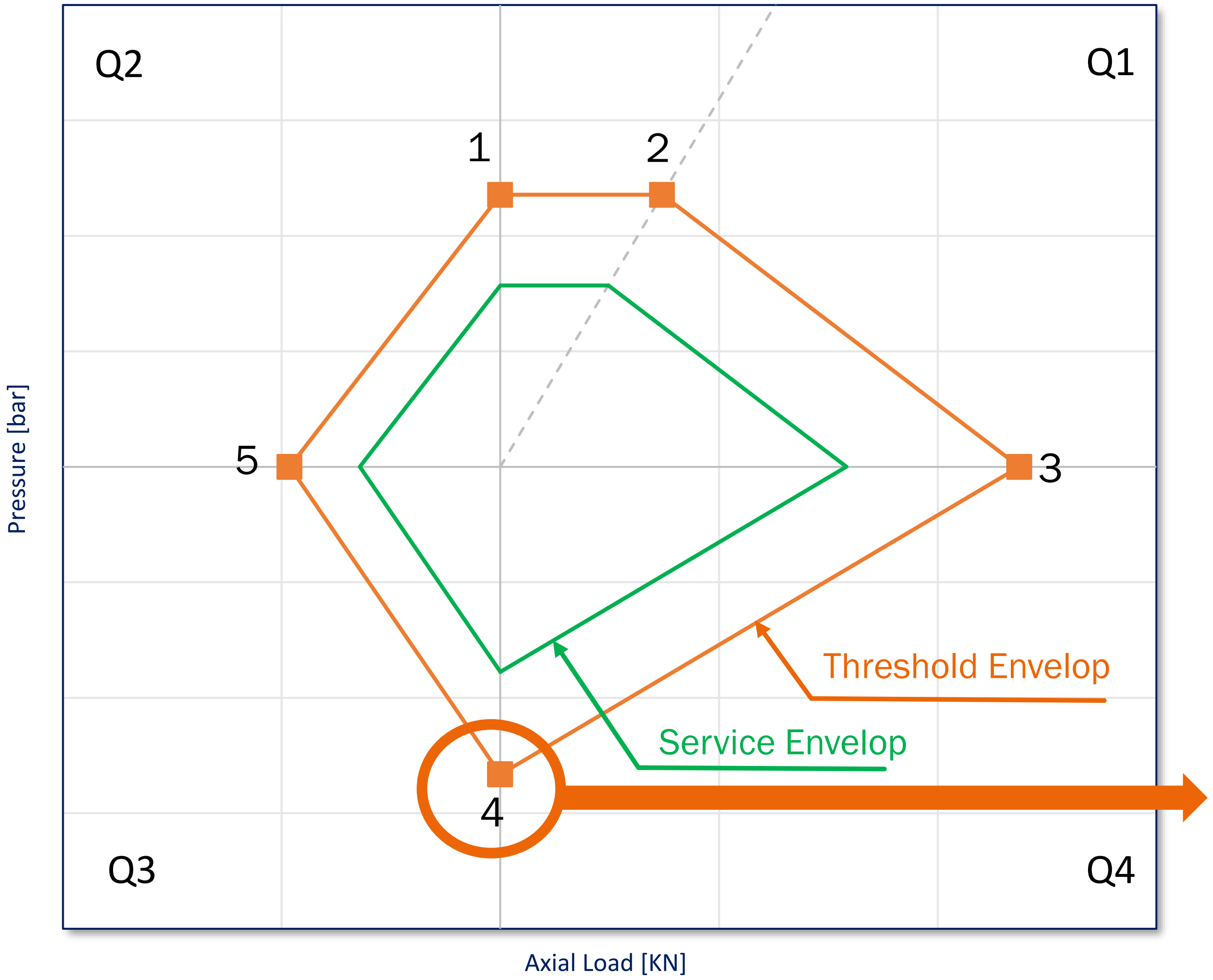
SERVICE ENVELOP – GRE COMPOSITE TUBULARS



Point 3 – <u>axial tensile threshold</u>:

- ISO 14692:2 provides a procedure for axial tensile threshold that works for industrial piping and pipelines, but for downhole tubulars more accuracy is needed.
- ASTM D2105 '*Standard Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube*' provides a well recognized procedure for the ultimate tensile strength, but not for axial tensile threshold.
- Optical strain measurements has shown useful potential for threshold determination, but so far not mature enough to be included in code and work for all composite downhole tubulars.
- Ongoing work in GRE/GEO: survival tests at constant axial loads measuring strain over time.

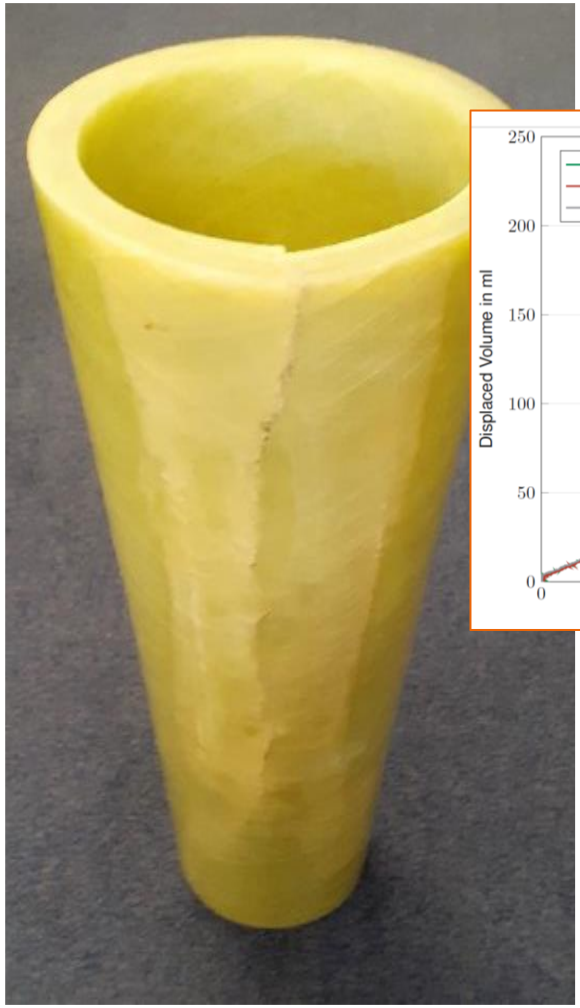
SERVICE ENVELOP – GRE COMPOSITE TUBULARS

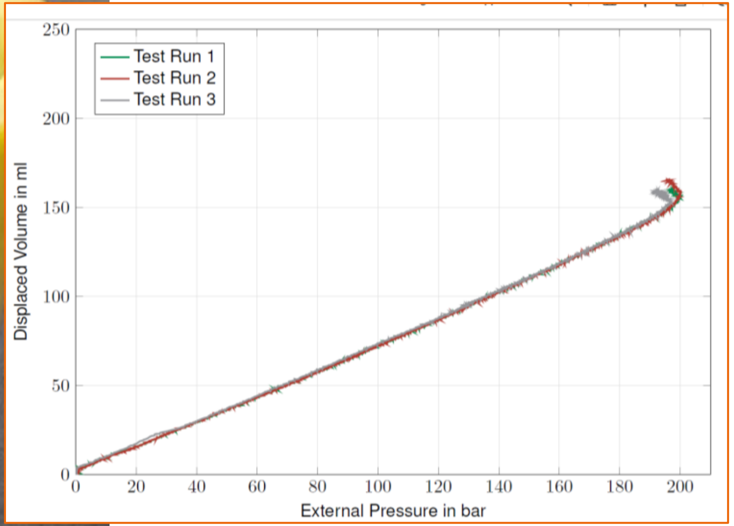


Point 4 – collapse pressure threshold:

- ASTM D2924 *'Standard Test Method for External Pressure Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe'* provides a well-established collapse test procedure, distinguishing two failure types:
  - Elastic (or buckling) collapse.
  - Compressive collapse.

SERVICE ENVELOP – GRE COMPOSITE TUBULARS

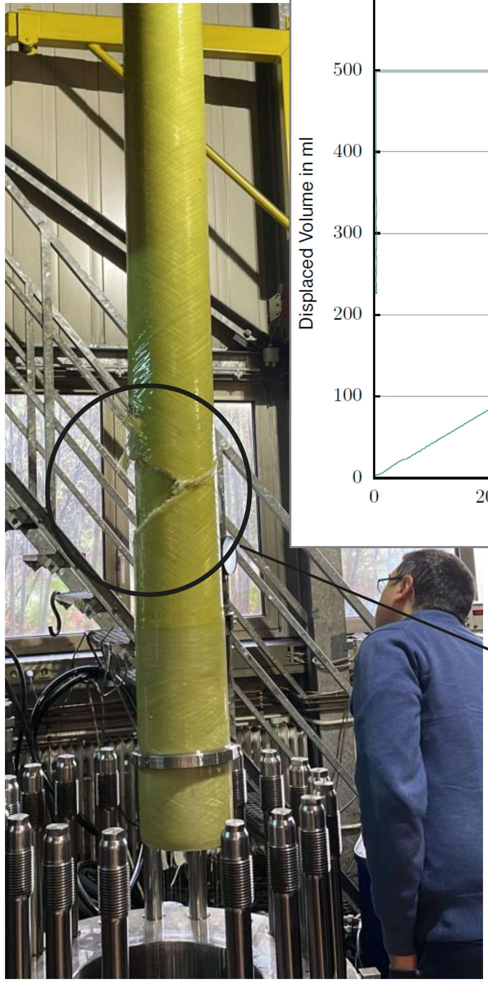


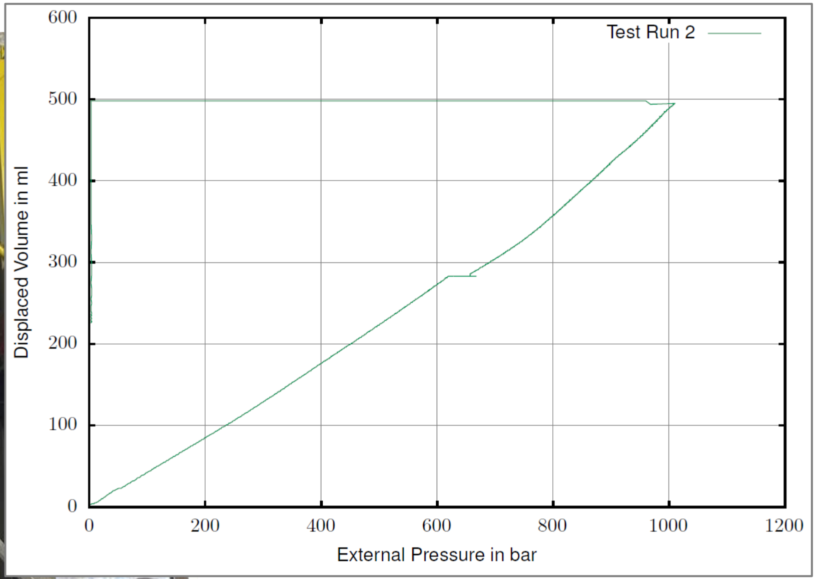


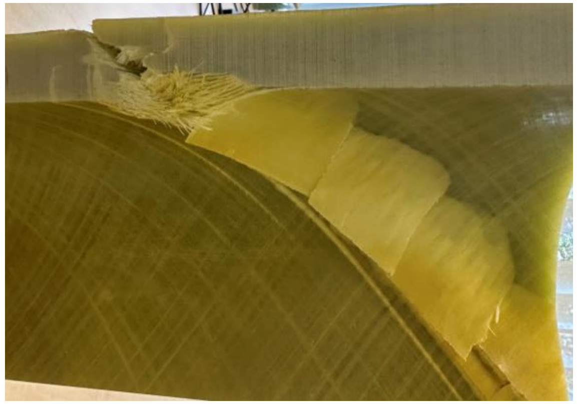
Elastic collapse:

- Exceeding the elastic hoop stability.
- Sharp discontinuity in the pressure-volume change graph.
  - Test may be stopped at that point to avoid full collapse.
  - This way, same sample may be tested several times, showing comparable collapse pressures.
- Fracture in the test specimen appearing as an axially oriented crack at full collapse.

SERVICE ENVELOP – GRE COMPOSITE TUBULARS



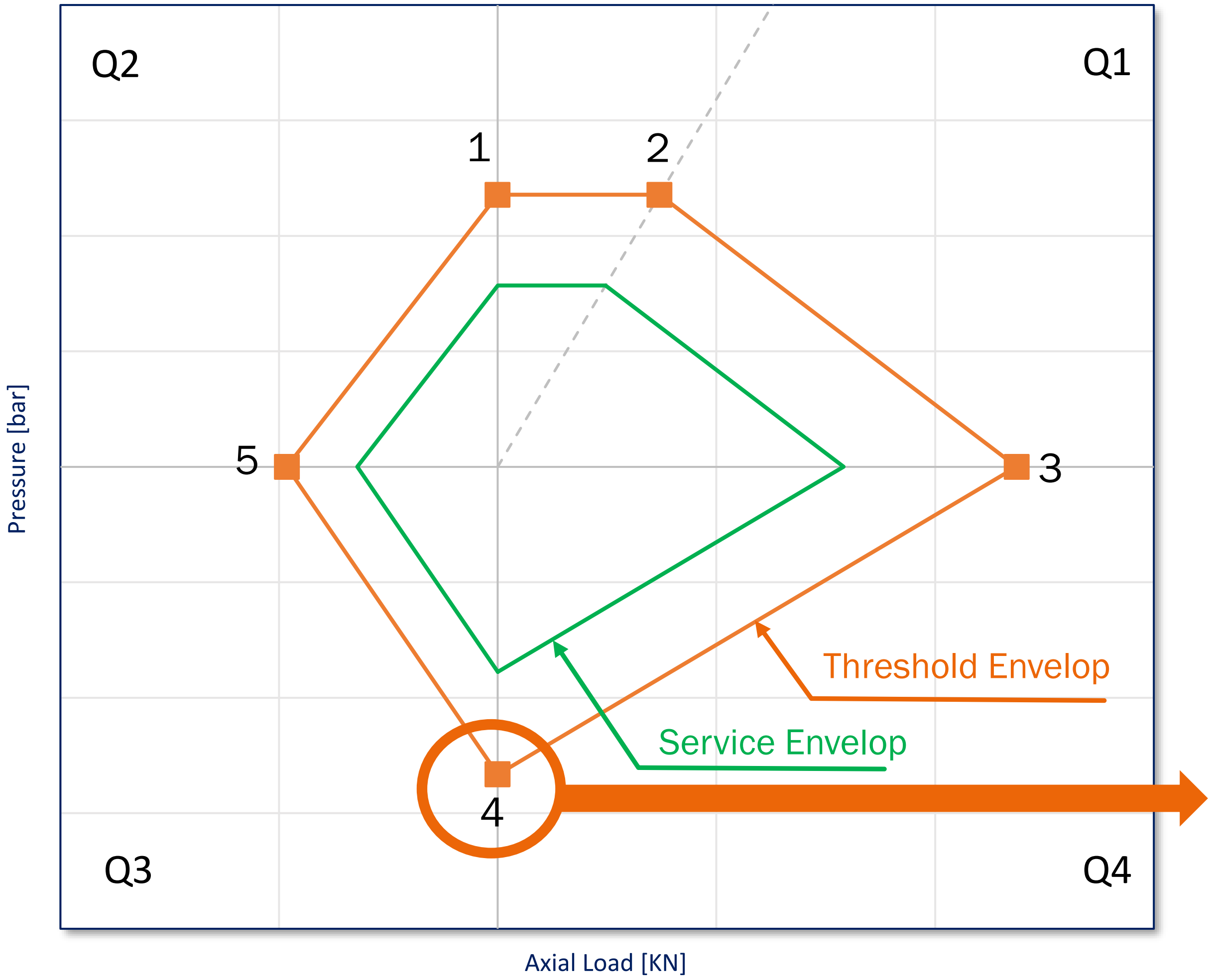




<u>Compressive collapse.</u>

- Exceeding the compressive hoop strength limits.
- Failure is usually identified by a sudden drop in pressure.
  - Nothing to react on in the pressure-volume change graph.
  - Test cannot be repeated on same sample.
- No longitudinal crack.

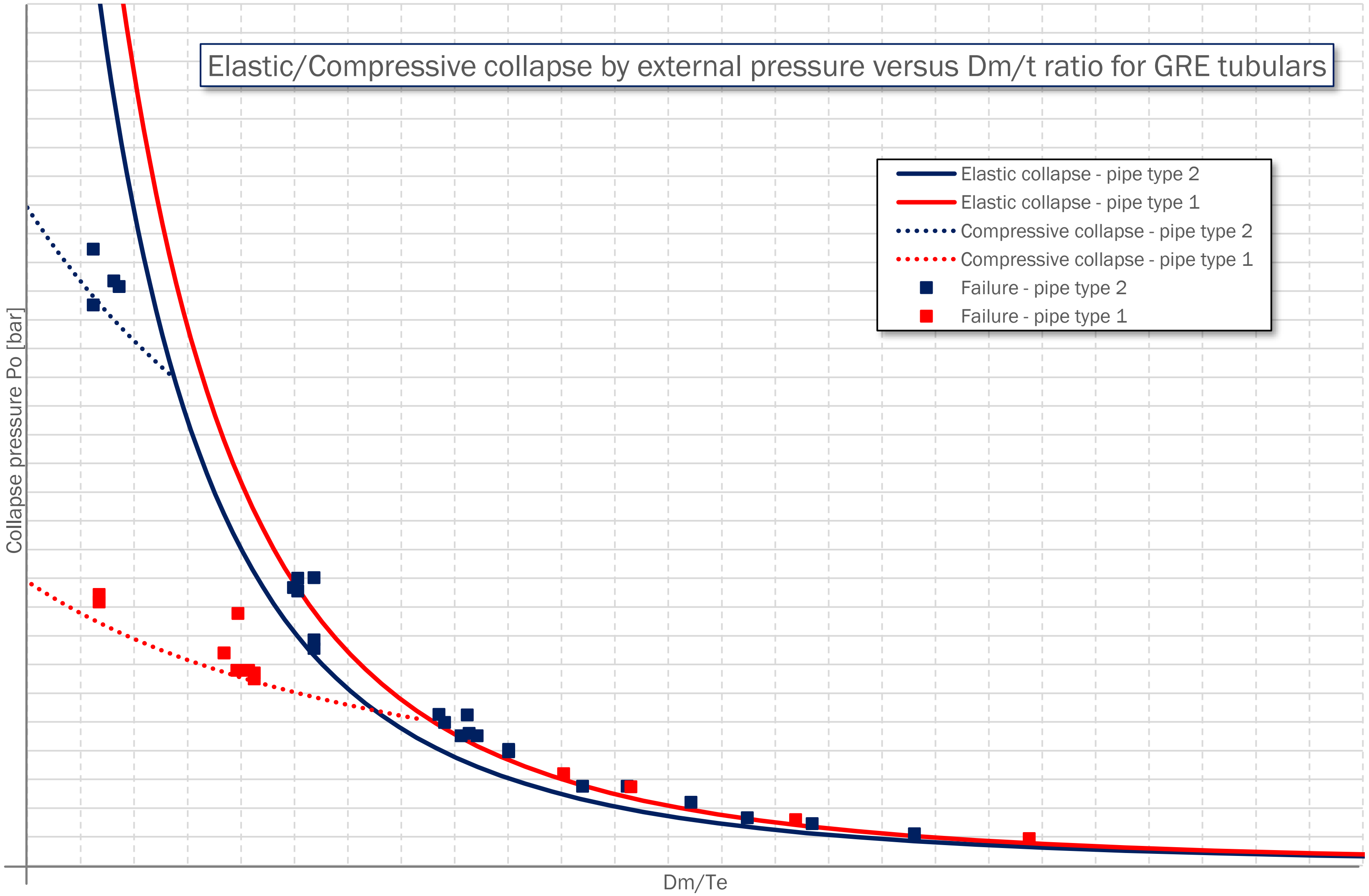
SERVICE ENVELOP – GRE COMPOSITE TUBULARS



Point 4 – <u>collapse pressure threshold:</u>

- Compressive collapse failure needs more research. Crack propagation over time may be involved. Hence, the compressive collapse mode shall be avoided.
- Collapse threshold is therefor to be related to elastic collapse only.
- To steer to elastic collapse only, GRE/GEO executed a collapse test program showing both compressive- and elastic collapse, for two different pipe designs.

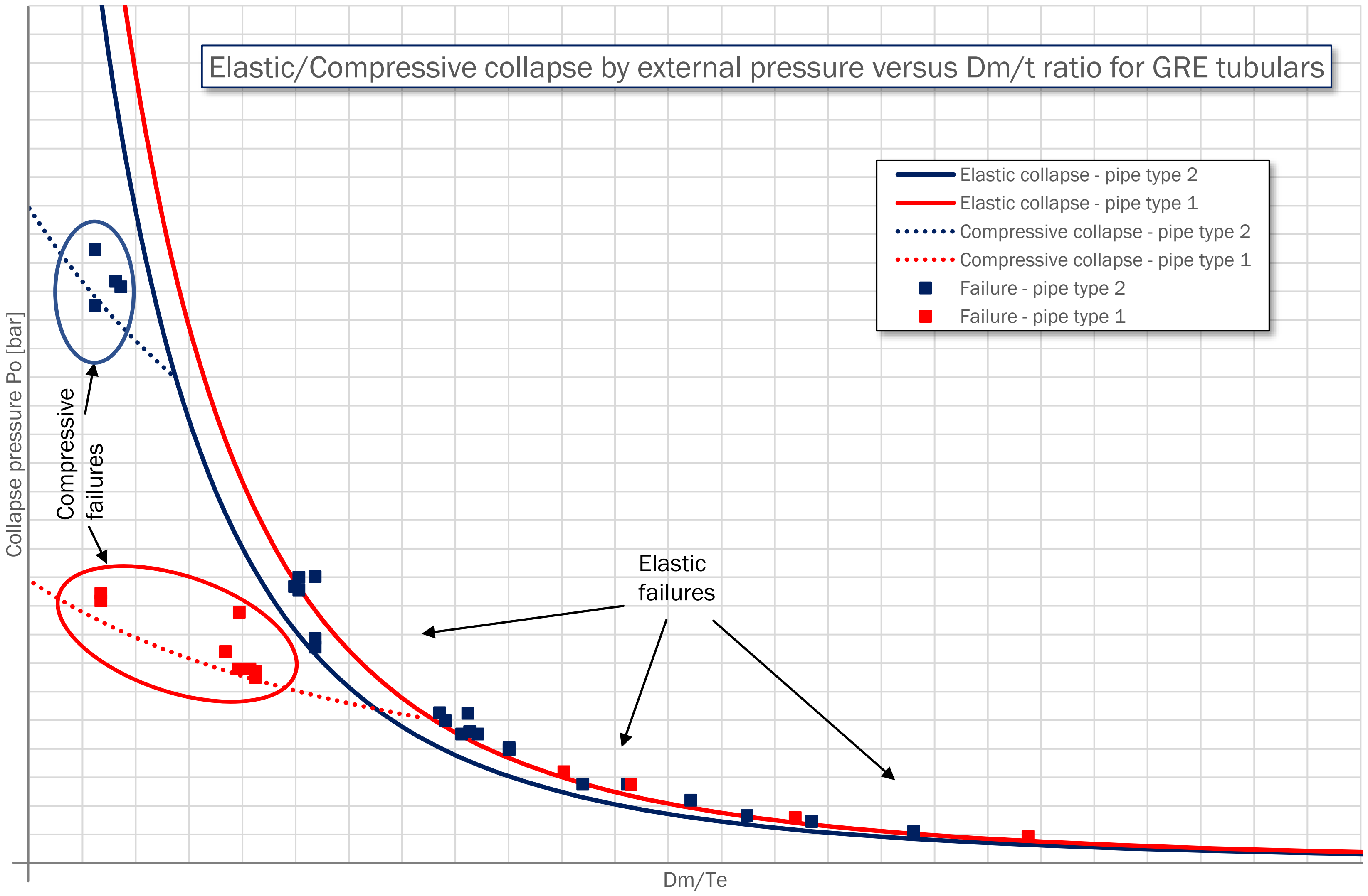
SERVICE ENVELOP – GRE COMPOSITE TUBULARS



Collapse program GRE/GEO

- 8″ and 4″ tubulars.
- Two GRE composite tubular designs.

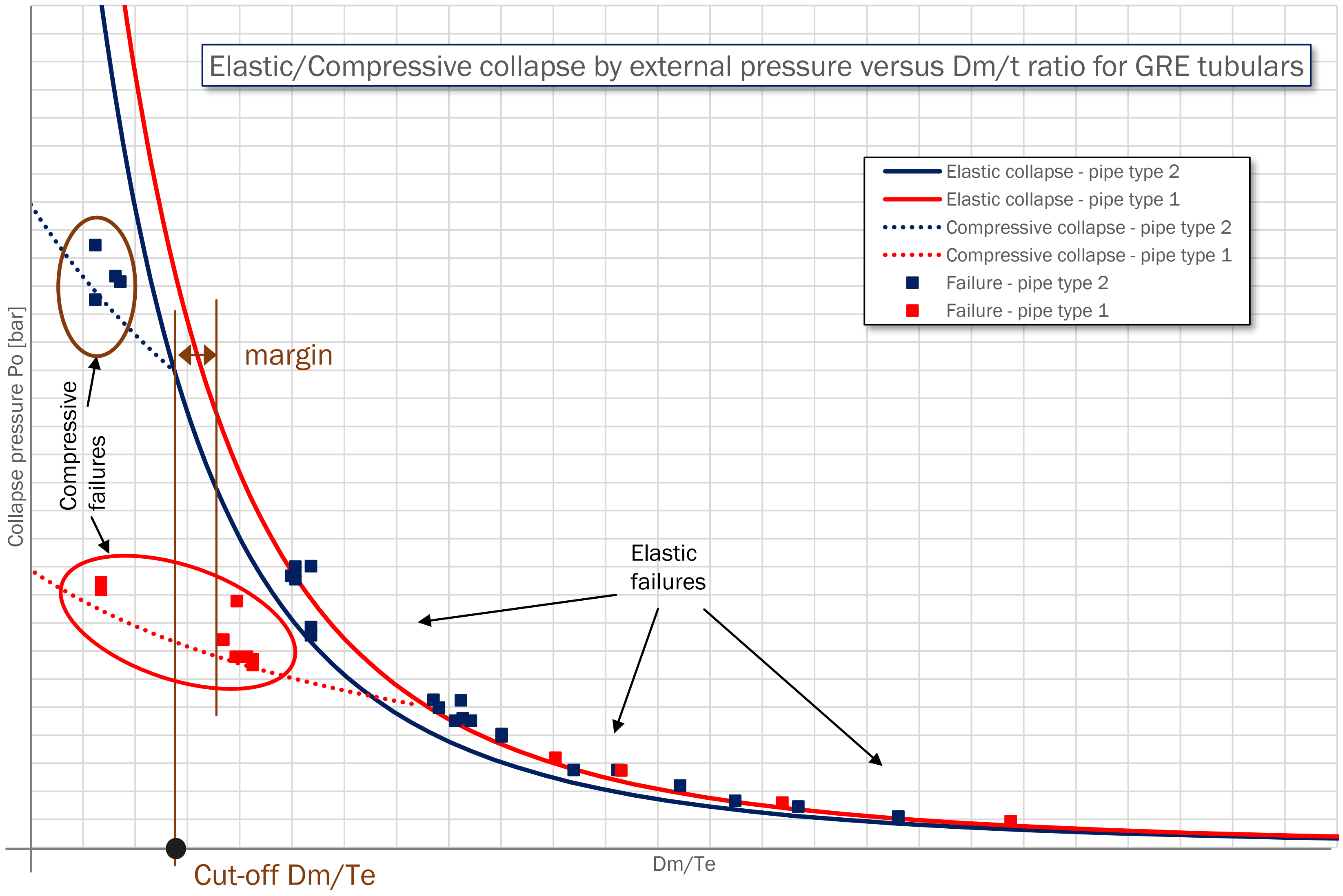
SERVICE ENVELOP – GRE COMPOSITE TUBULARS



Collapse program GRE/GEO

- 8" and 4" tubulars.
- Two GRE composite tubular designs.
- For a given composite tubular test several Dm/Te's resulting both elastic and compressive failures.

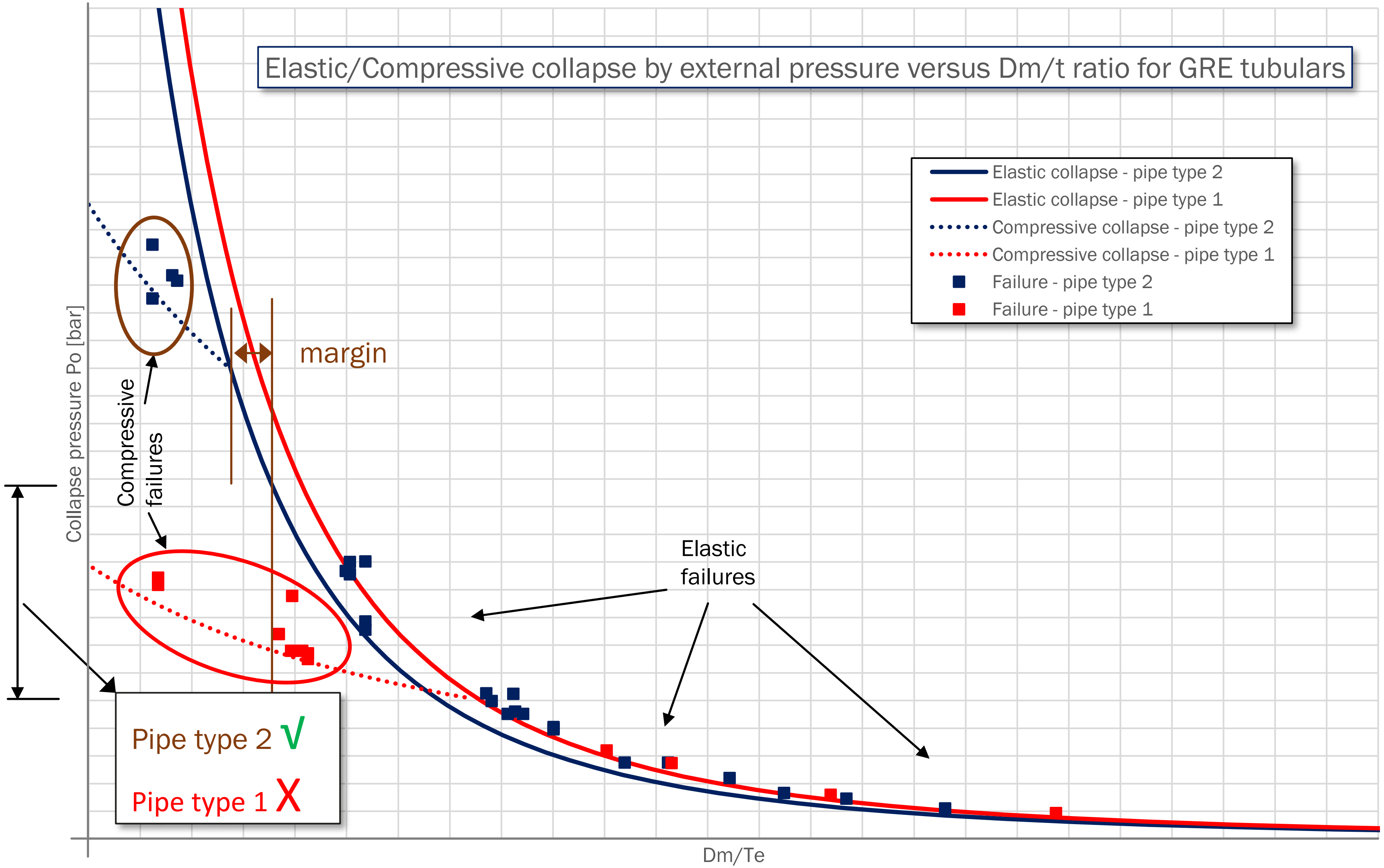
SERVICE ENVELOP – GRE COMPOSITE TUBULARS



Collapse program GRE/GEO

- 8″ and 4″ tubulars.
- Two GRE composite tubular designs.
- For a given composite tubular test several Dm/Te's resulting both elastic and compressive failures.
- Determine the 'cut-off' Dm/Te at the intersection of elastic- and compressive collapse behavior
- Set a margin to secure elastic collapse (work in progress)

SERVICE ENVELOP – GRE COMPOSITE TUBULARS

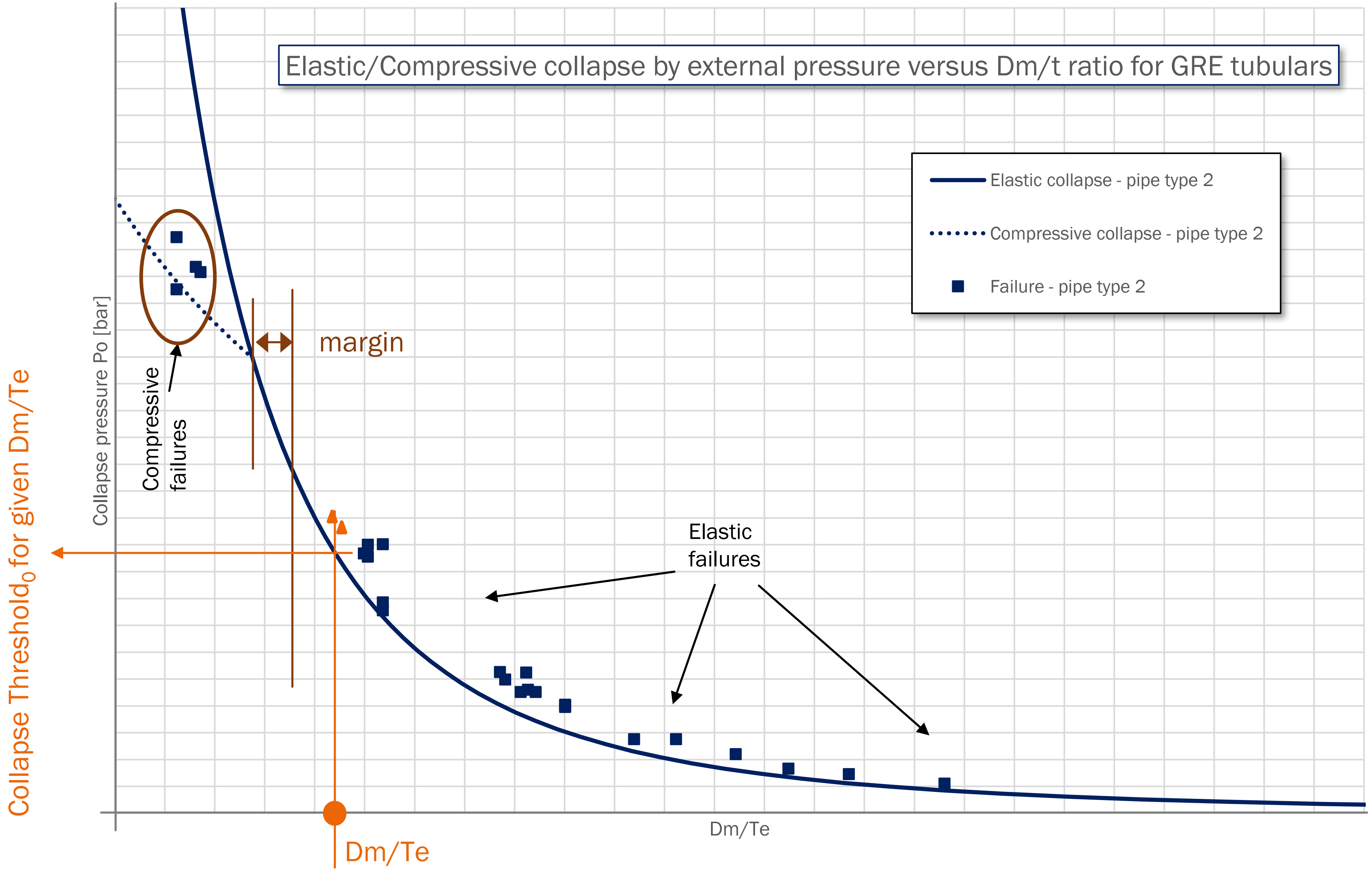


Collapse program GRE/GEO

In this test program, at indicated collapse pressures:

- Pipe type 2:
  elastic failure -> ok
- Pipe type 1:
  compressive failure -> not ok

SERVICE ENVELOP – GRE COMPOSITE TUBULARS

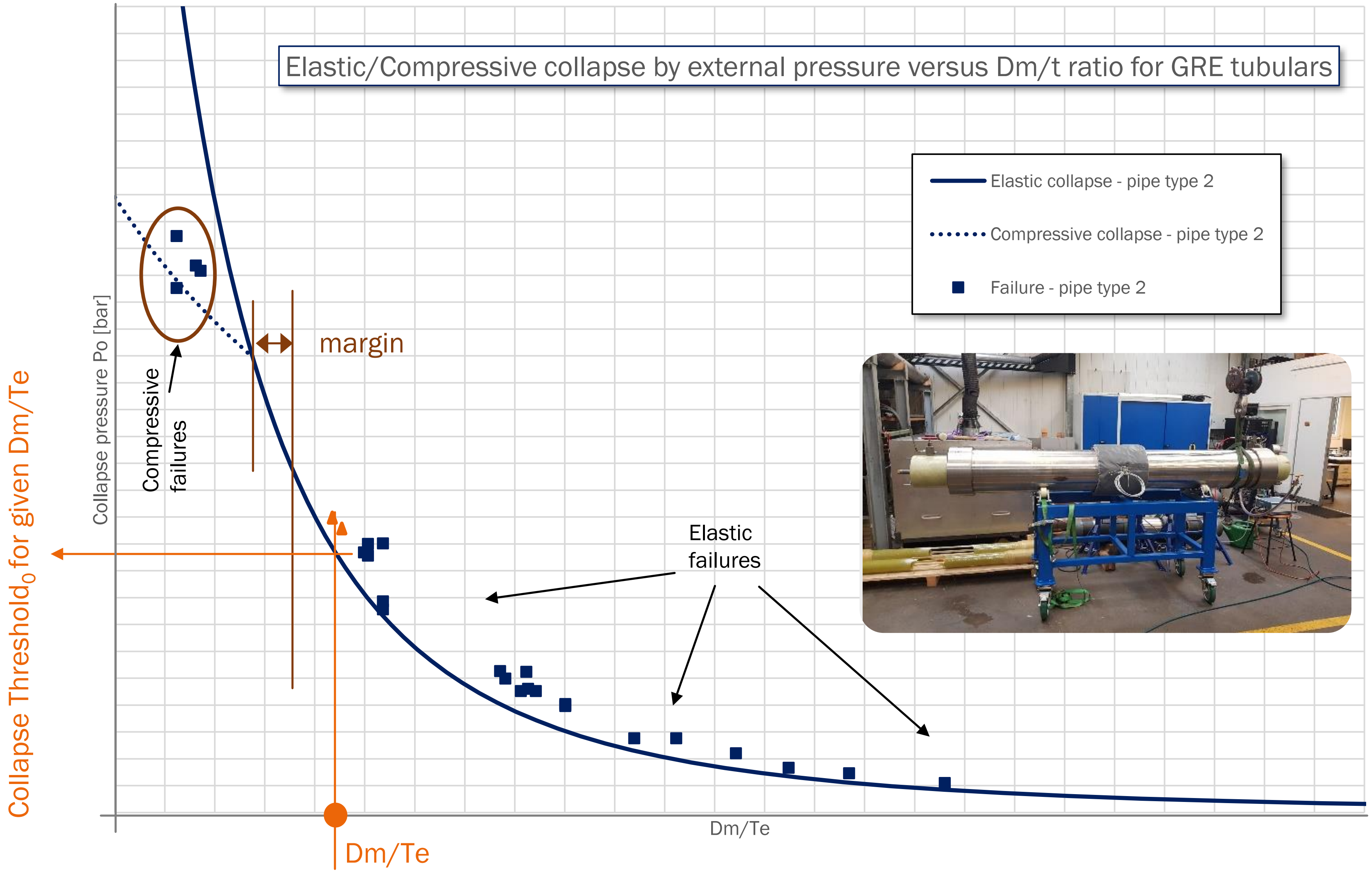


Collapse program GRE/GEO

Collapse threshold:

- For a given Dm/Te, the initial threshold$_0$ is the collapse pressure given by the intersection of that Dm/Te and the elastic collapse curve.
- The manufacturer need to test that Dm/Te to show:
  - Elastic collapse failure.
  - Compliance with the elastic collapse curve.
- This way, the available collapse data for a given GRE composite tubular will grow over time.

SERVICE ENVELOP – GRE COMPOSITE TUBULARS



Collapse program GRE/GEO

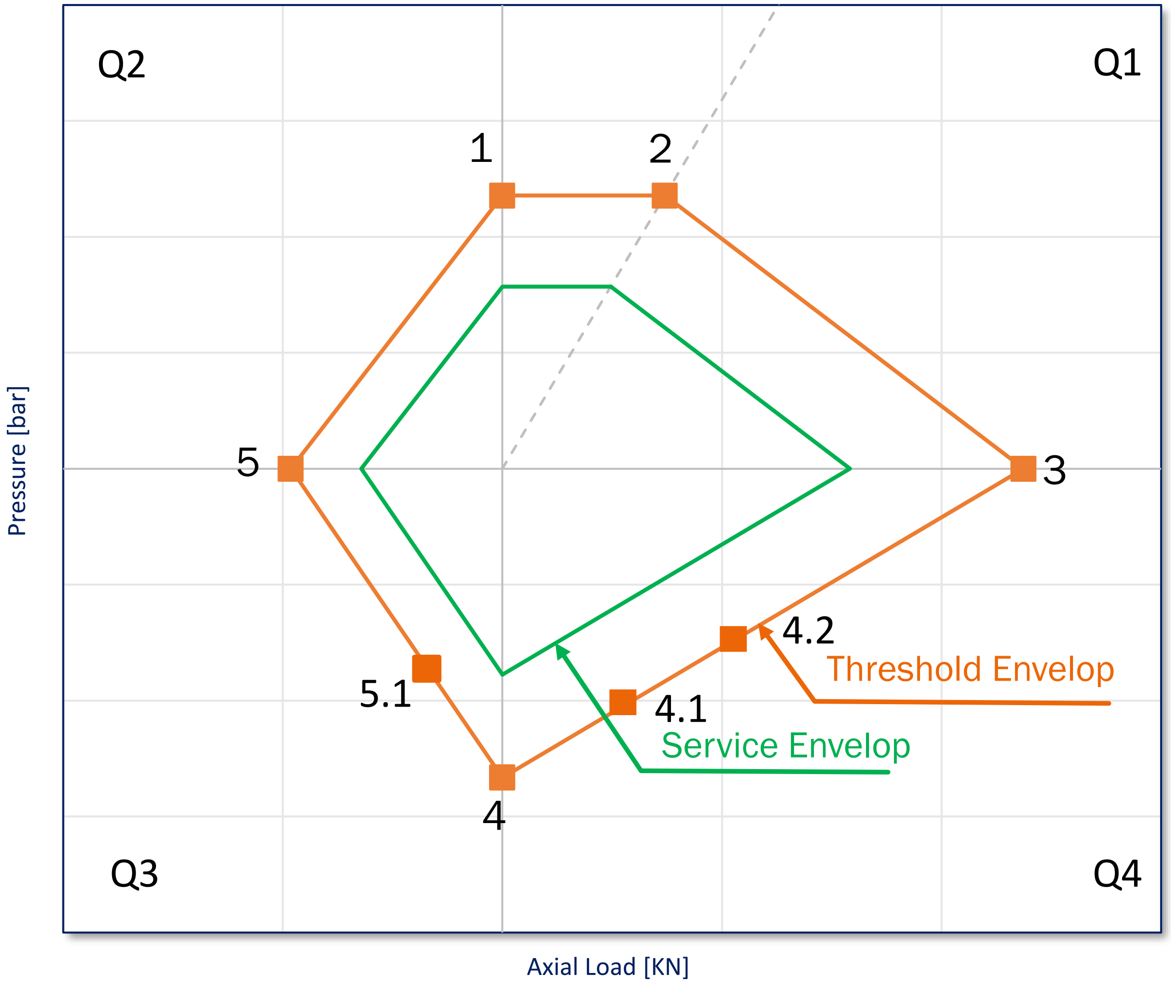
Collapse threshold:

- The collapse threshold is set equal to:

$$\frac{Threshold_0}{time\ \&\ temperature\ effects}$$

- Time- and temperature effects are addressed by
  - Effects on elastic properties (ISO 10471).
  - Cementing loads: 100 hr collapse survival test at design temperature.
  - Sustained loads: 1000 hr collapse survival test at design temperature.

SERVICE ENVELOP – GRE COMPOSITE TUBULARS



Work in progress:

- Combined loads.
- Test:
  - Combined collapse & axial tension (4.1 and 4.2)
  - Combined collapse and axial compression (5.1)
- This work may lead to somewhat enlarged service envelop.

Question and Answer

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THANK YOU FOR YOUR ATTENTION!

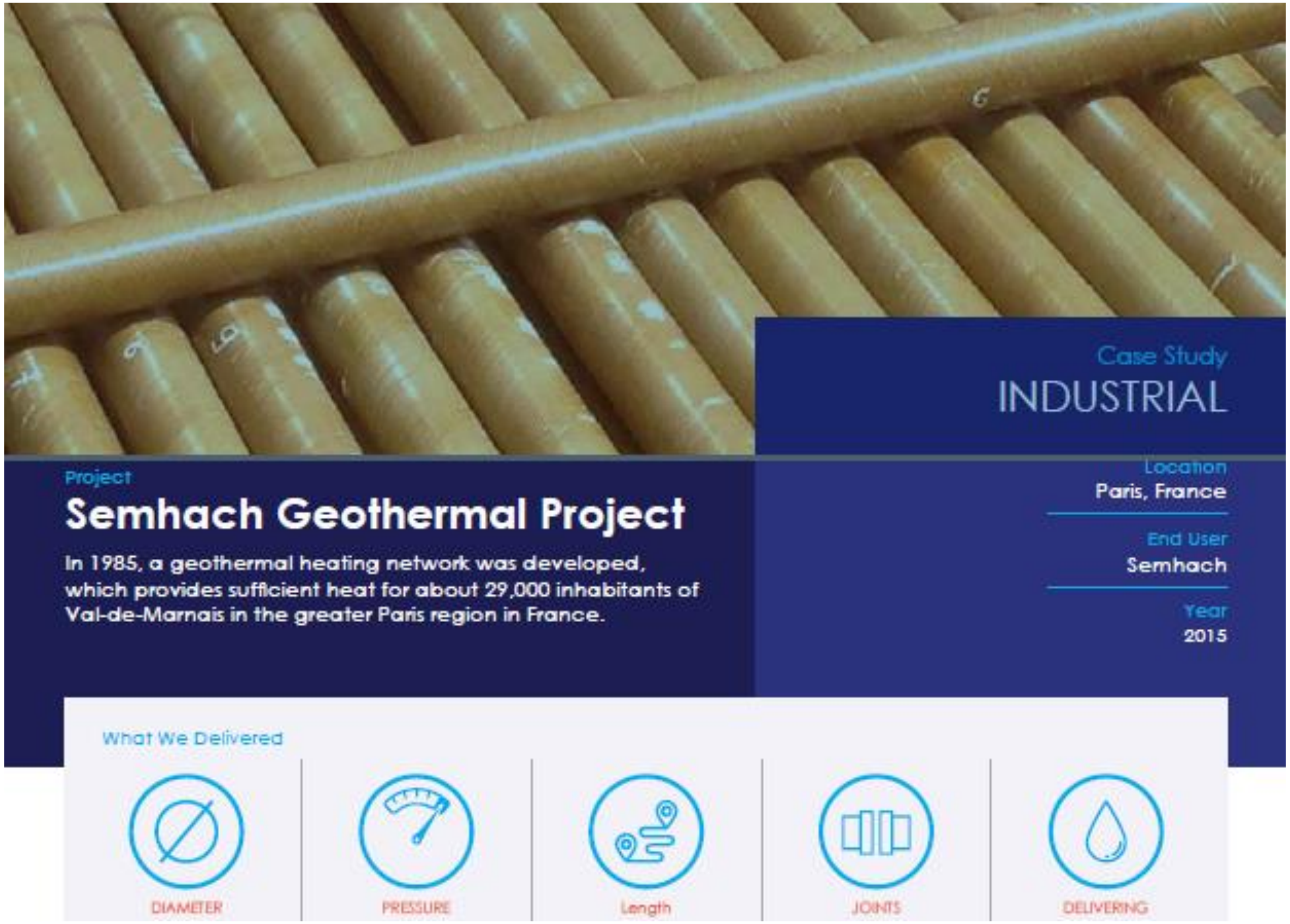
DER GEOTHERMIEKONGRESS - OCTOBER 2023, ESSEN, GERMANY

HERMEN VELTKAMP, FUTURE PIPE INDUSTRIES

CASE STUDIES

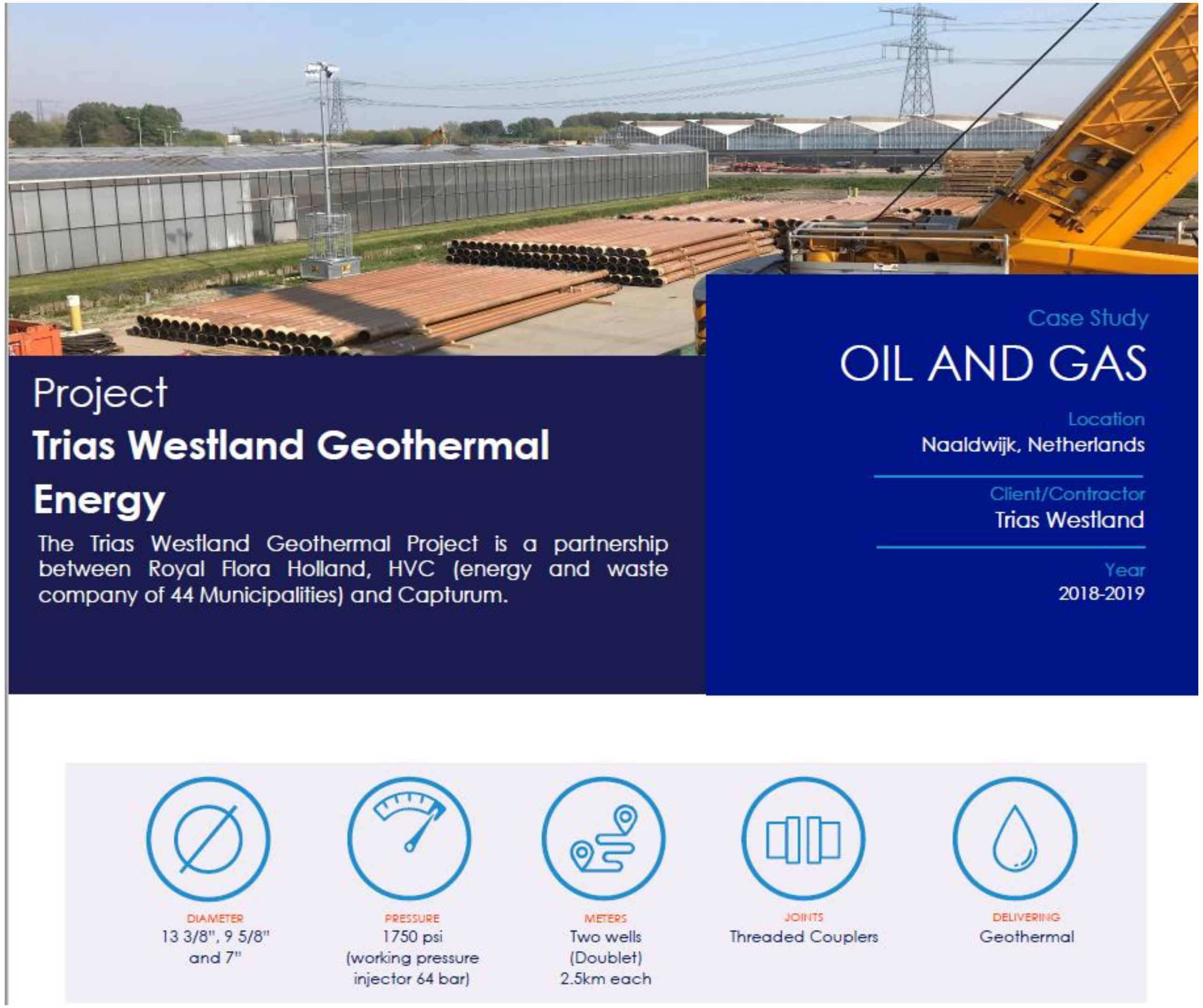
CASE HISTORIES AND LOOK-OUT

- 2015 – District heating
- Cemented in steel casing
- 7" - API 5B - 8 rnd thread



CASE HISTORIES AND LOOK-OUT

- 2018 - Horticulture
- Full composite tapered string and cross-overs
- Free hanging at wellhead with PBR
- Challenges: OD couplers and re-installation



CASE HISTORIES AND LOOK-OUT

- 2021 – Heating of building
- Free hanging tubing with PBR sealing the annulus
- Use of new designed thread and full glass couplers

CASE HISTORIES AND LOOK-OUT

- 2023 – District heating
- Full composite tapered casing - cemented
- Hybrid coupler – special new designed thread
- De and re-installation 5,75% rejects out of 174 joints

CASE HISTORIES AND LOOK-OUT

- Catwalk
- Pipe protectors
- Single joint elevator
- handslips and air power slips
- Powertong with back-up

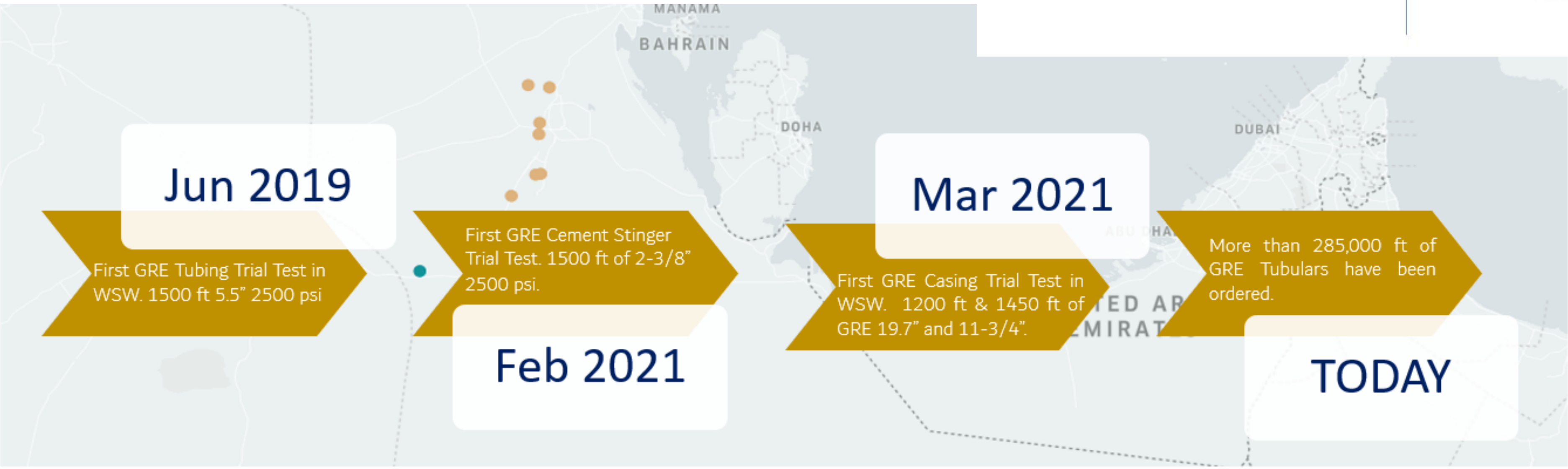
CASE HISTORIES AND LOOK-OUT

- **2024 -Aramco casing project**
- FPI downhole Journey with Saudi Aramco
- Cooperation

aramco

FPi FUTURE PIPE INDUSTRIES

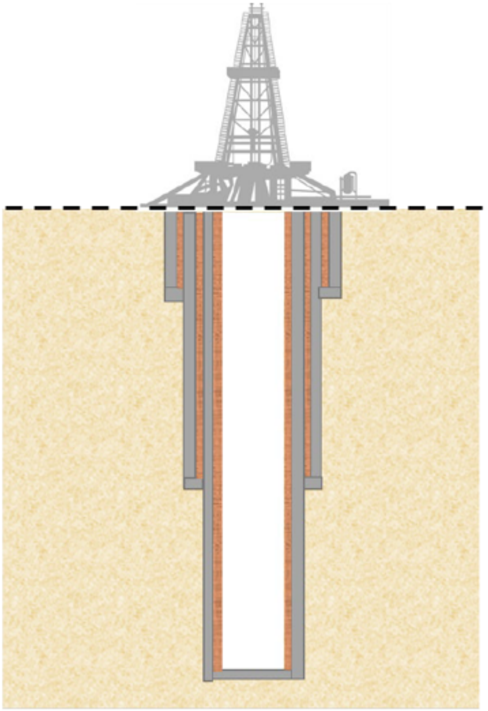
slb
HALLIBURTON
Baker Hughes
FRANK'S INTERNATIONAL
Weatherford
interwell
DOWNHOLE PRODUCTS
MAXWELL Oil Tools
AMCO امكو



CASE HISTORIES AND LOOK-OUT

Downhole-Casing Journey with Aramco

Downstrong®RedBox®



Current deployed products:

Power injection wells

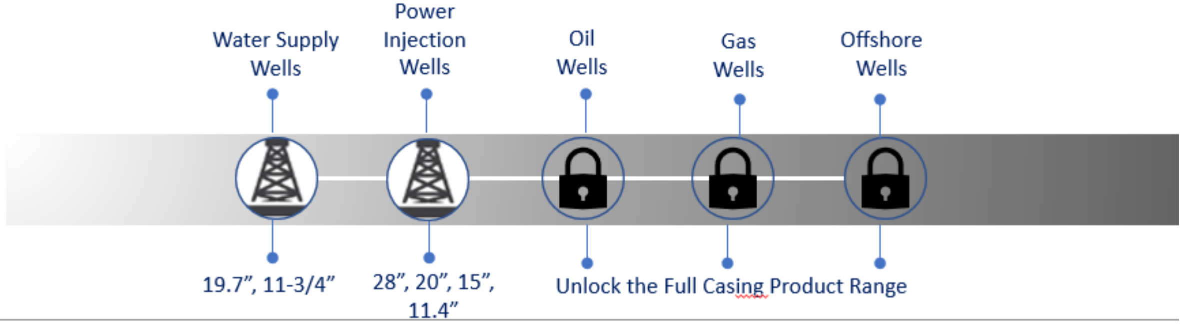
- 28" 4RD T&C, CP 438 psi & BP 400 psi series*
- 20" 4RD T&C, CP 885 psi & BP 450 psi series*
- 15" 4RD T&C, CP 1640 psi & BP 1500 psi series*
- 11.4" 4RD T&C, CP 3150 psi & BP 2500 psi series*
- 7-5/8" 4RD T&C, BP 2500 psi series*

Water Supply Well 2021

- 19.7" RSLJ, CP 900 psi & BP 450 psi series
- 11-3/4" 4RD T&C, CP 810 psi & BP 850 psi series

Key Advantages:

- Lower CAPEX, OPEX, and Life Cycle Cost (LCC).
- Anti-Corrosion & Light Weight.
- Uses similar handling and running tools of conventional OCTG tubulars.
- Green solution - lower carbon emissions.



- Hybrid coupler
- 10.000ft deviated well
- Annular BOP test successful
- Retrievable bridge plug test
- Casing tests 2021 successful
- Input GRE-GEO implemented

Question and Answer

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THANK YOU FOR YOUR ATTENTION!