Carbon Fiber PA12 TCP for Oil and Gas applications - Qualification

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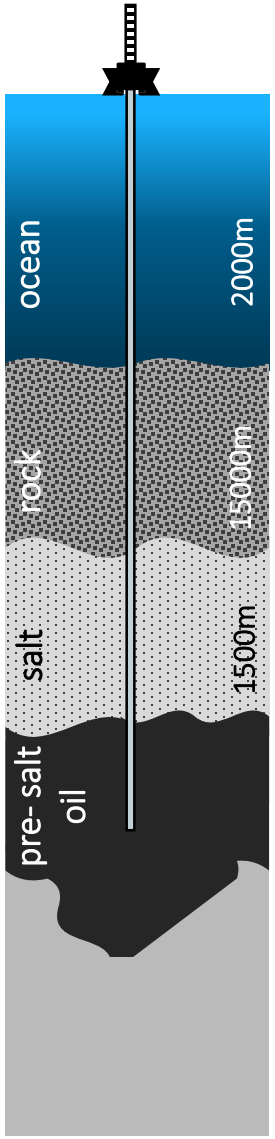
Background – Answering Oil & Gas industry challenges

Challenges for the offshore Oil and Gas industry

- Current development focus on deep-water fields
- Water depth of more than **2000m**
- High pressure / high temperature reservoirs: **600 bar / 110°C**
- High corrosive load of crudes and gases: **organic acids, H_2S, CO_2**

How to ensure production in a most economical and most reliable way and at minimal environmental risk ???



Outline

- Introduction
  - Flexible pipes for Oil & Gas
  - Thermoplastic Composite Pipe
  - Materials for Oil & Gas
  - DNV standard for Composite Pipes
- Qualification and Design Approach
- Material Qualification
  - Testing conditions
  - Extensive testing
  - Testing durations
- Material models
- Current status
  - Static test results
  - Test setup development
  - Model matching from coupon to pipe performance
- Concluding remarks

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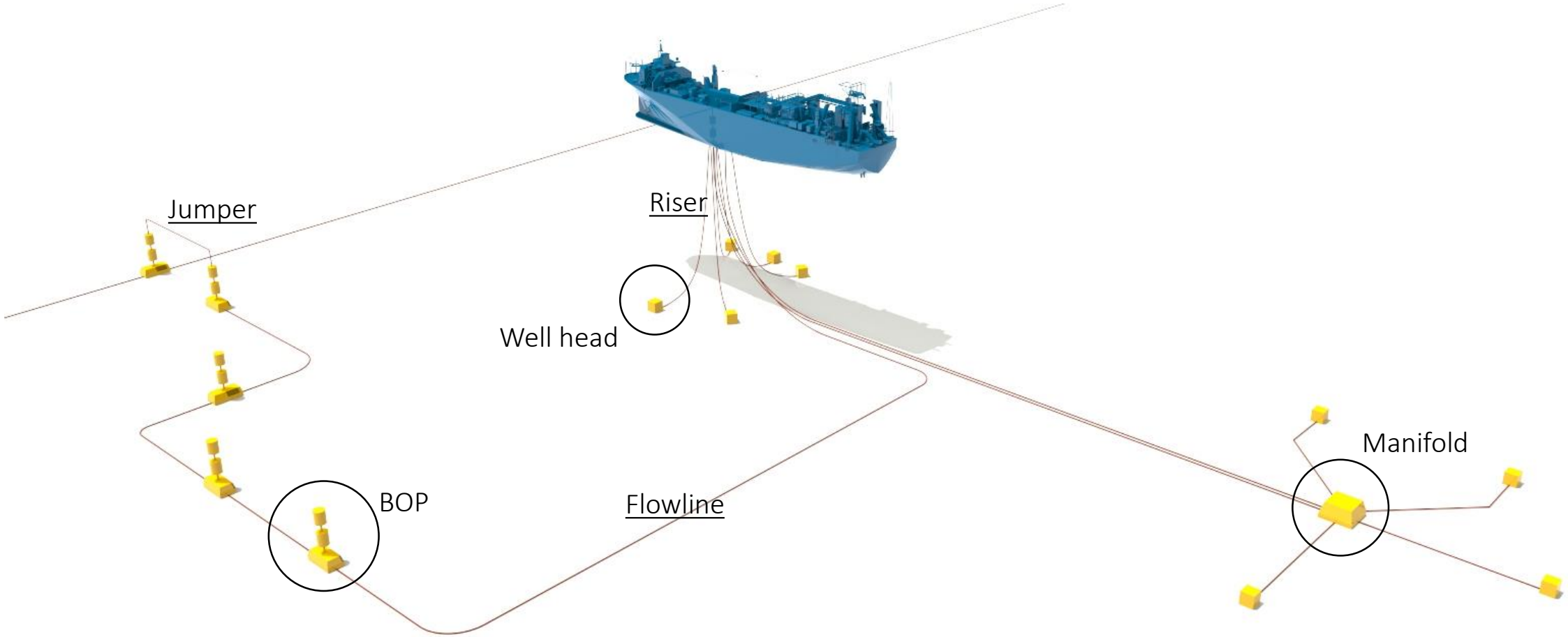
Introduction (1) – Flexible pipes for Oil & Gas industry



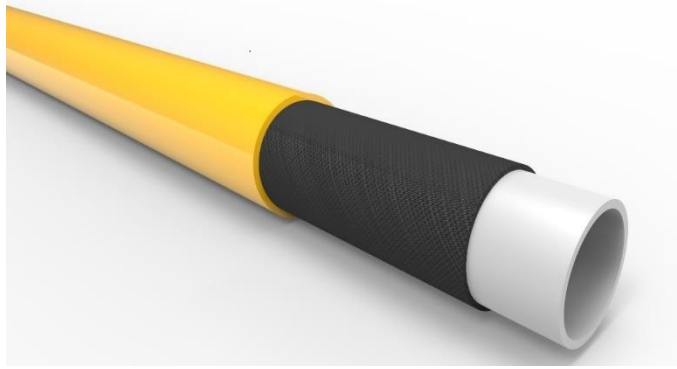
Introduction (2) – TCP overview

conventional flexible pipe

- Unbonded layers of steel and polymers
- Long and successful track record
- At their limit for cost efficiency regarding corrosion resistance for newer more challenging environments in greenfield applications
- weight limitations for dynamic risers can occur with greater water depths

hybrid pipe

thermoplastic composite pipe (TCP)



- Fully bonded polymer/composites system
- Novel approach for challenging projects
- Design foregoing steel armor
- strength from thermoplastic UD composite tapes taking combined load cases
- corrosion insensitive carbon fiber
- Spoolable onto small diameter reel
- Multilayerliner solutions possible

Introduction (3) – Oil & Gas materials

- Steel is the de-facto standard in the Oil & Gas industry
  - Low cost
  - Long track record
  - Standards and procedures are build around steel

- Polymers have key advantages over steel
  - Corrosion resistance
  - Low density

Material	Temperature rating	Chemical resistance	Handling/ processing	Price/ performance
Steel	+ + +	-	-	+ + +
Polyolefins	o	+	+ + +	+ +
Polyamides	+	+ +	+ +	+
PVDF	+ +	+ + +	+	-
PEEK	+ + +	+ + +	-	- - -

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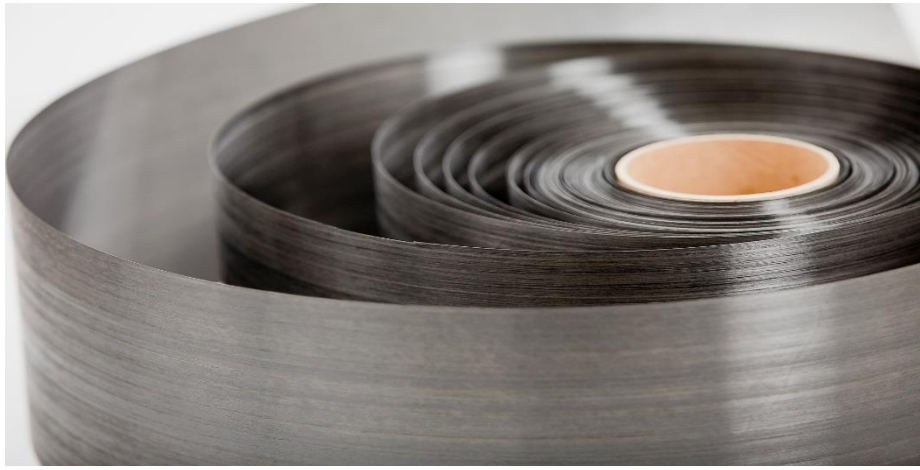
Introduction (4) – CF-PA12 as an Oil & Gas material

PA12 VESTAMID NRG ®

- Different PA12 grades are in use for unbonded flexibles (liner, cover, wear tapes, etc.)
- Material with successful track record in O&G flexibles since 2006 (API qualified)
- Very good resistance vs. Oil & Gas hydrocarbons, corrosive environments and Rapid Gas Decompression (RGD)
- Large temperature range: from arctic conditions to 72°C for 25 years
- Well known and predictable long-term ageing behavior



CF PA12 UD-Tape VESTAPE ®

- Continuous unidirectional carbon fibre reinforced tape is under full qualification for TCP applications in water, hydrocarbons and sour service

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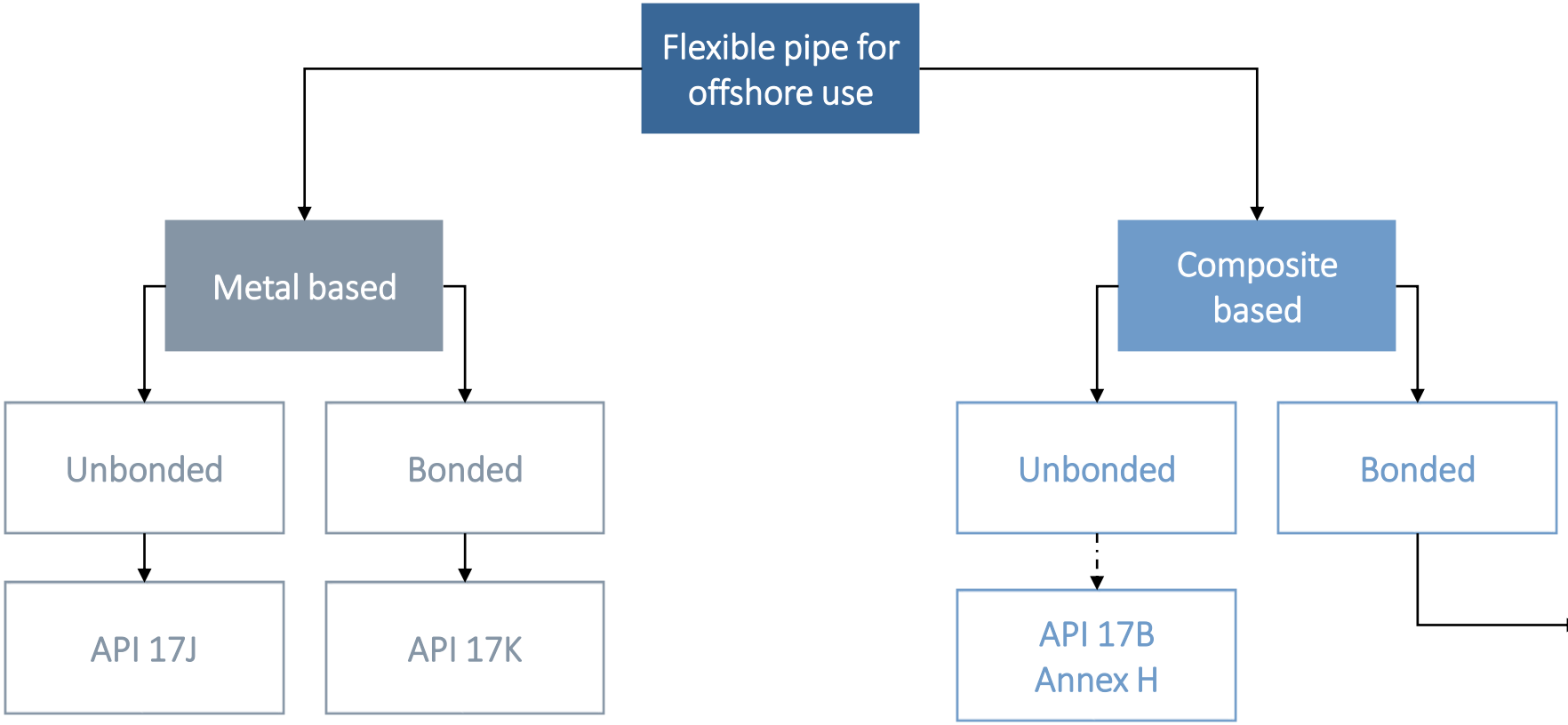
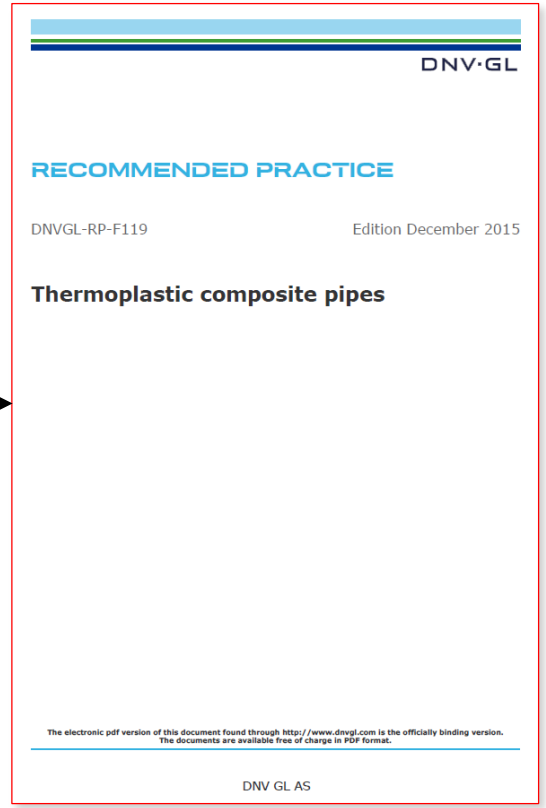
Introduction (3) – DNV standard for Composite Pipes





DNV·GL

RECOMMENDED PRACTICE

DNVGL-RP-F119 Edition December 2015

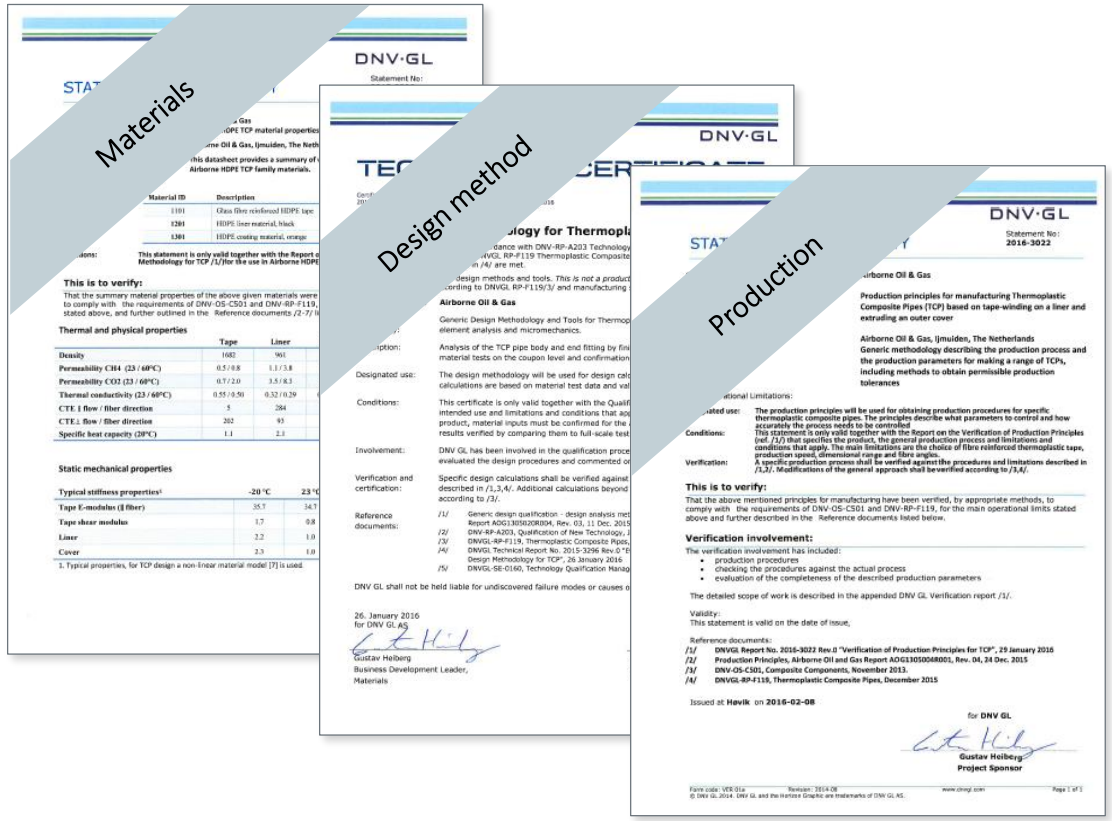
Thermoplastic composite pipes

The electronic pdf version of this document found through http://www.dnvgl.com is the officially binding version. The documents are available free of charge in PDF format.

DNV GL AS

Introduction (3) - DNVGL-ST-F119 – Oil & Gas qualification

Generic



Product

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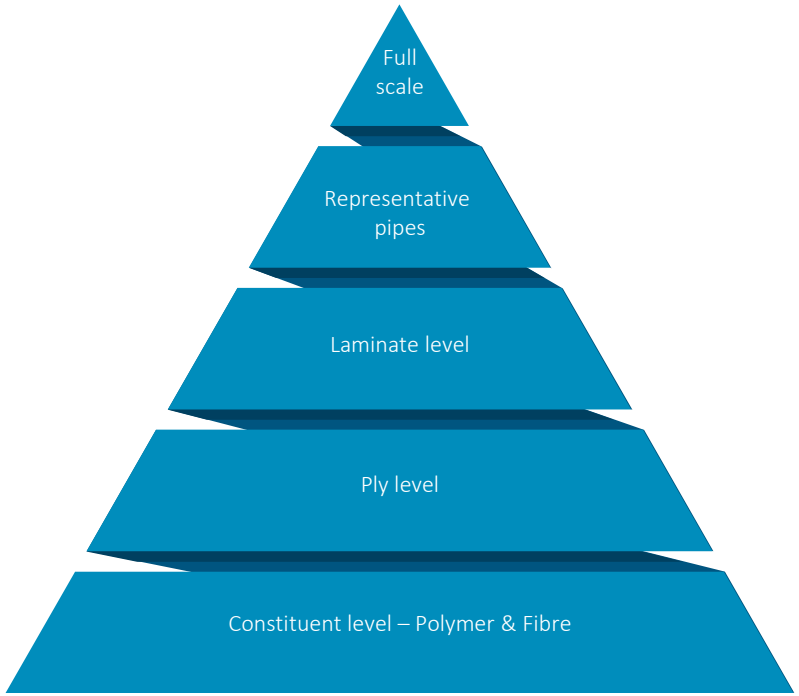
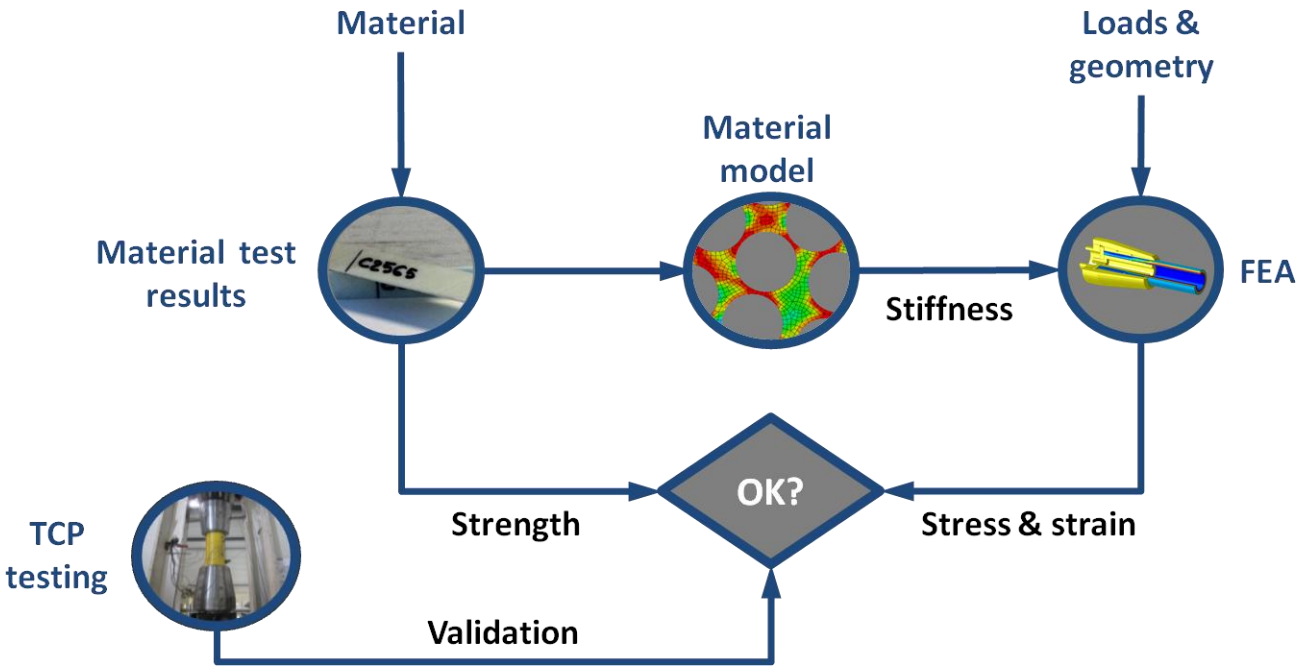
Qualification and Design Approach

Specific
- Product

Generic
- Materials
- Design: TCP & End-fitting
- Production



- Predictive engineering approach
- Extensive material testing and modeling
- Limited full-scale validation tests



Material Qualification (1) – Challenging test conditions

- Acc. to ST-F119 conditions in testing need to be representative to oilfield/application condition

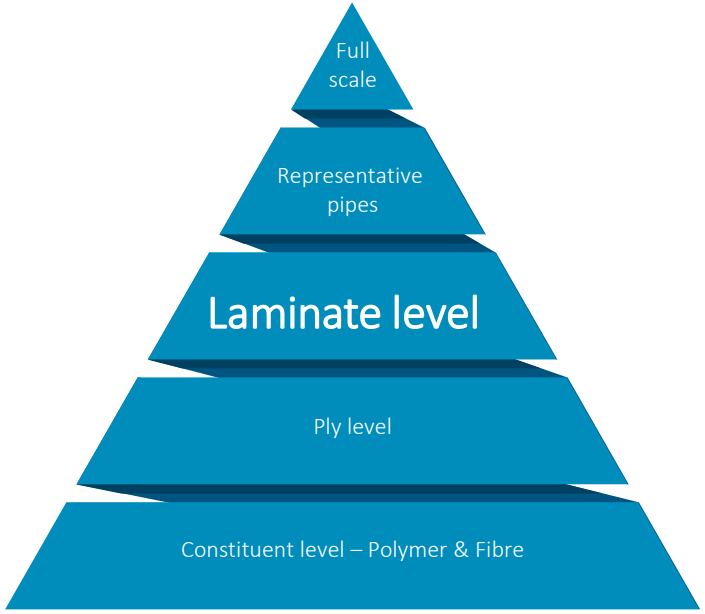
- standardized candidates for crudes, gases, drilling or completion fluids, scale inhibitors, hydrate blockers and many more are:
  - Water, Pentane, Cyclohexane, Toluene, Ethanol, Methanol, Hydrochloric acid, Sulfuric acid, Carbon dioxide, Hydrogen sulfide, Methane, …
  - Many of them in combination at elevated temperatures and pressures
  - Impact CF PA12 physically and/or chemically

  - But : condition also refers to state of the product (virgin to end of life) and needs to be assessed as critical part in the qualification

Material Qualification (2) – Extensive testing

- A typical TCP qualification includes a large amount of coupon testing for static, stress rupture and fatigue to cover all possible failure mechanisms and shifts thereof
- Up to 900 specimens can be needed for basic static alone at several temperatures and environments when qualifying for low safety factors

static	virgin				physical impact				chemical impact			
	CTD	RTD	ETD1	ETD2	CTD	RTD	ETD1	ETD2	CTD	RTD	ETD1	ETD2
Tension 0°	15	15	15	15	15	15	15	15	15	15	15	15
Tension 90°	15	15	15	15	15	15	15	15	15	15	15	15
In-plane-shear (IPS)	15	15	15	15	15	15	15	15	15	15	15	15
Compression	15	15	15	15	15	15	15	15	15	15	15	15
Inter-laminar shear strength (ILSS)	15	15	15	15	15	15	15	15	15	15	15	15



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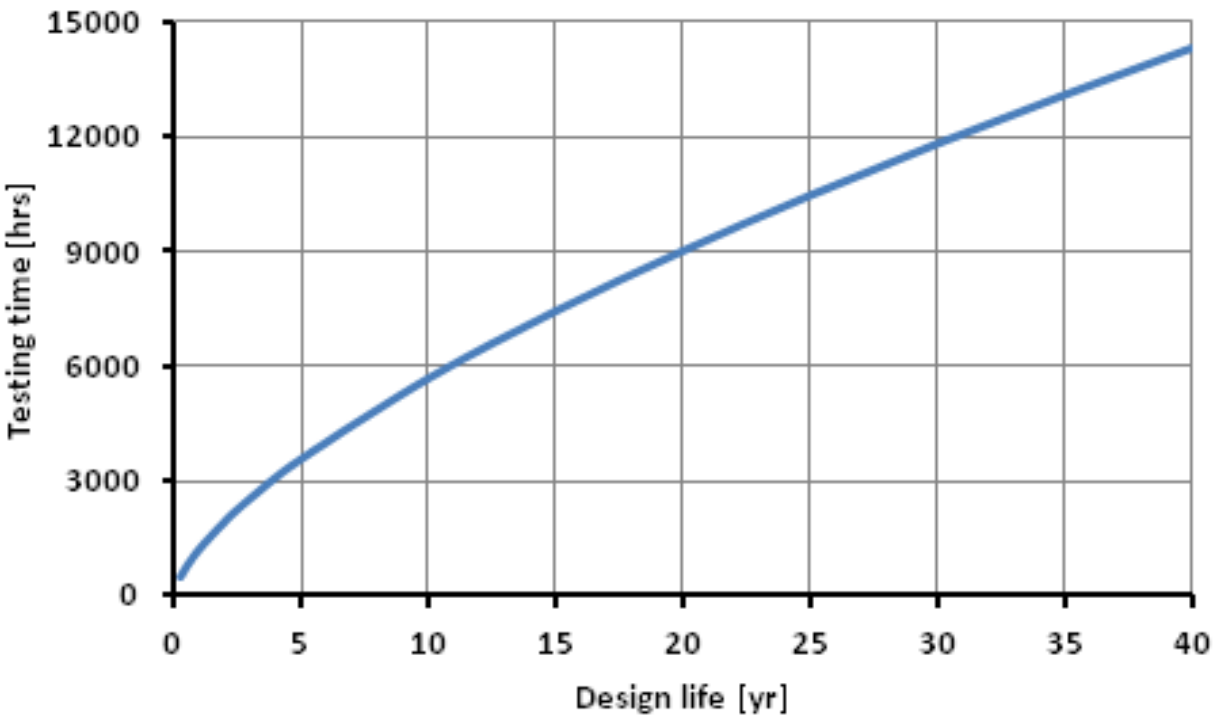
Material Qualification (3) – long test durations

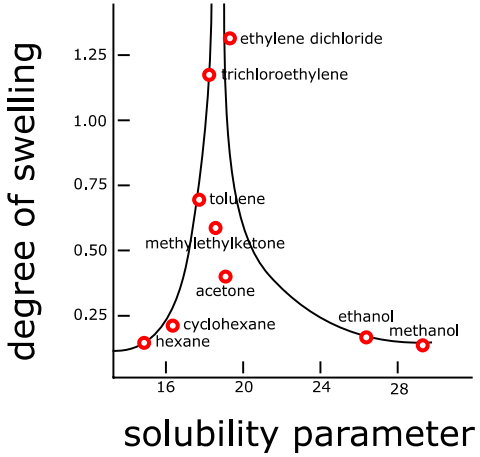
- Time of testing and end of life criteria
- ST-F119 correlates a service life of 30 years to 12,500h of exposure testing in stress rupture
- Task: predict long term behavior of exposed specimen in terms of different failure modes in order to design setups



Material Models – Towards all application conditions

Solubility

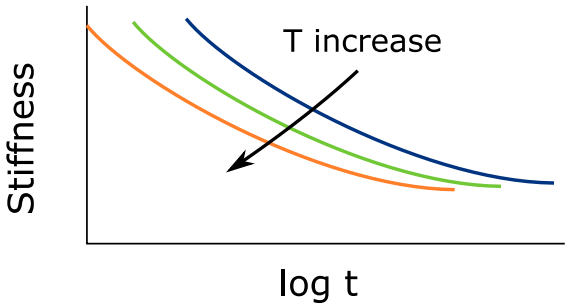
- Determination of swelling based on cohesive energy



Reduction of test environment

Time-Temperature superposition

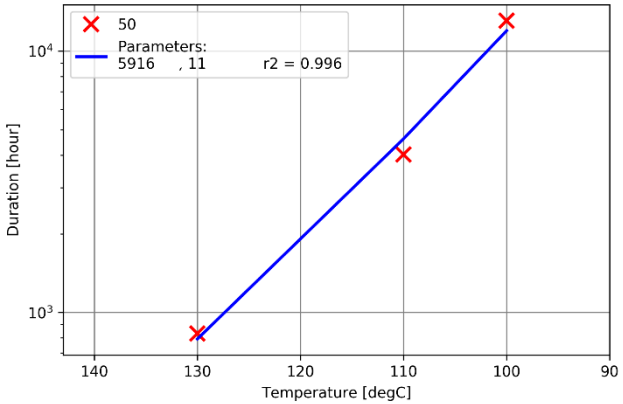
- Relation between viscoelastic dependent properties, time and temperature



Reduction of test duration

Arrhenius equation

- Determination of the rate of chemical effects with temperature



Accelerated ageing

Status (1)

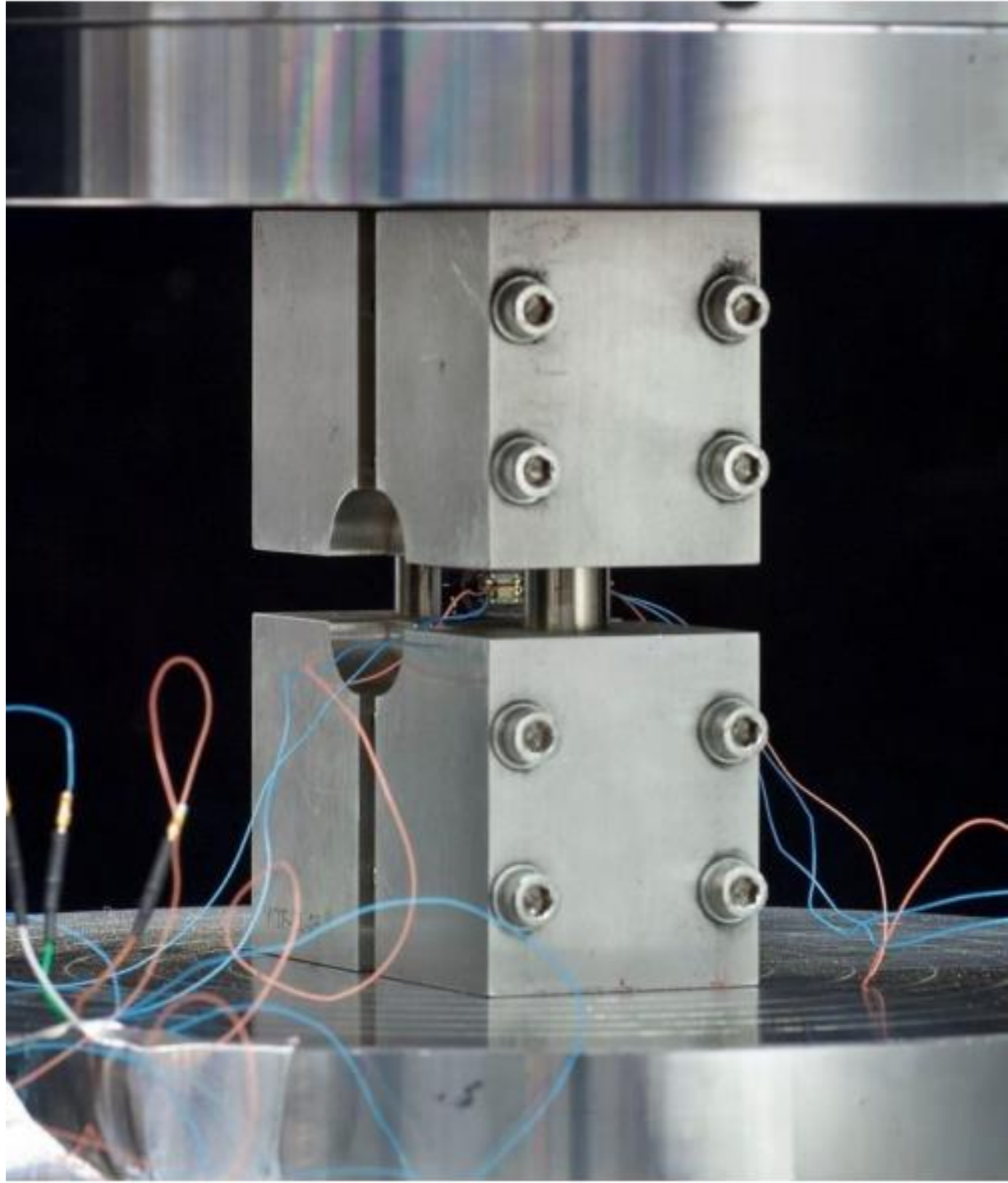
On-going material qualification

- Technical difficulties solved

- First results show good resistance in the representative fluid (NORSOK M710)
  - Close to unconditioned material
  - Across all failure mechanisms

- Long-term behavior as expected
- Fatigue behaviour as expected

- End of live performance testing: ongoing



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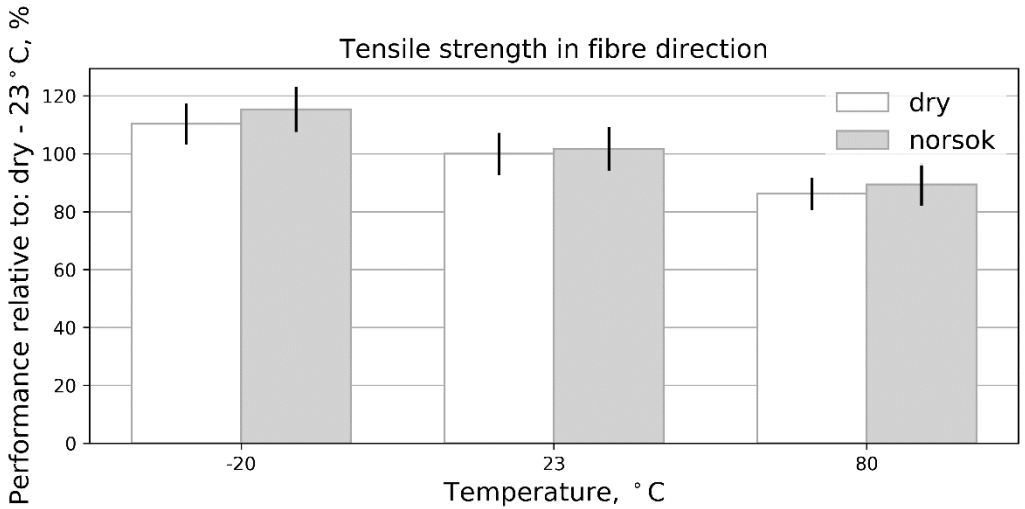
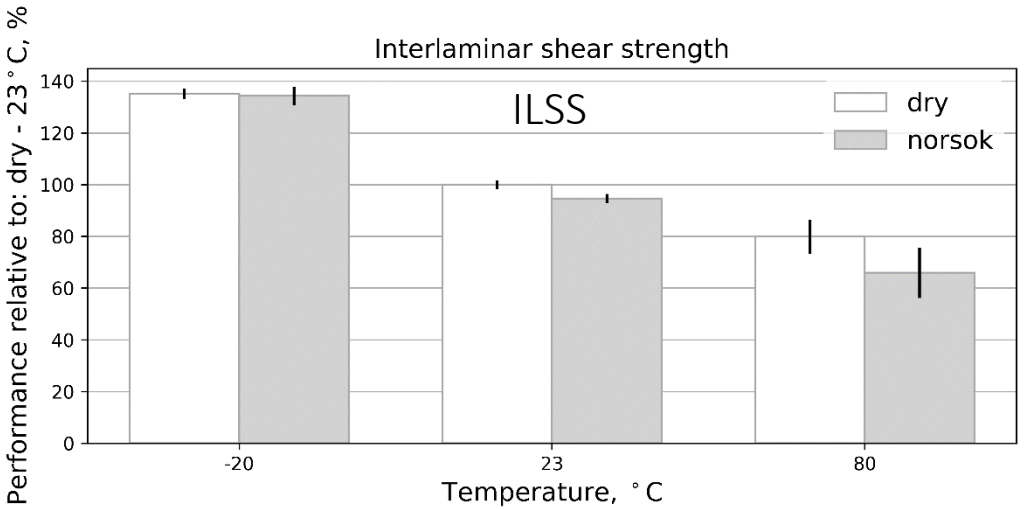
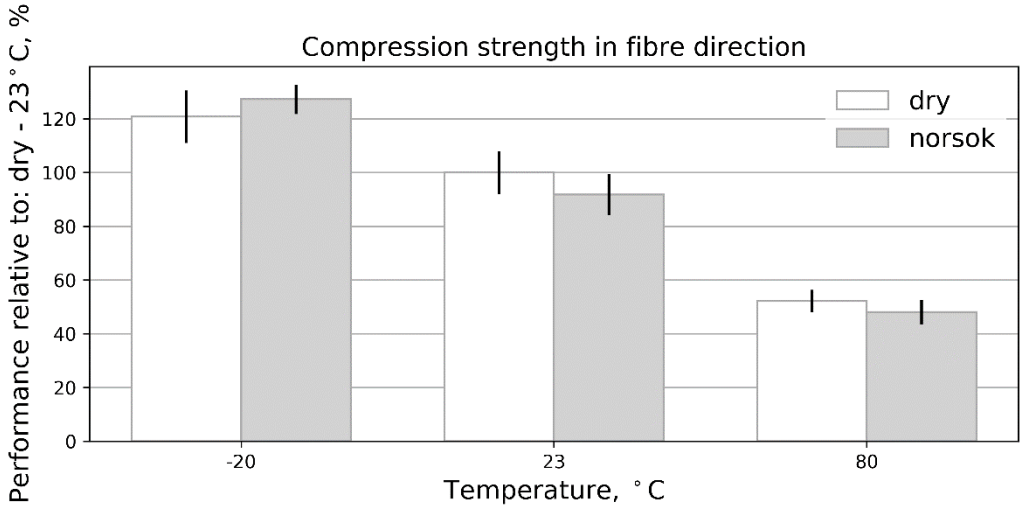
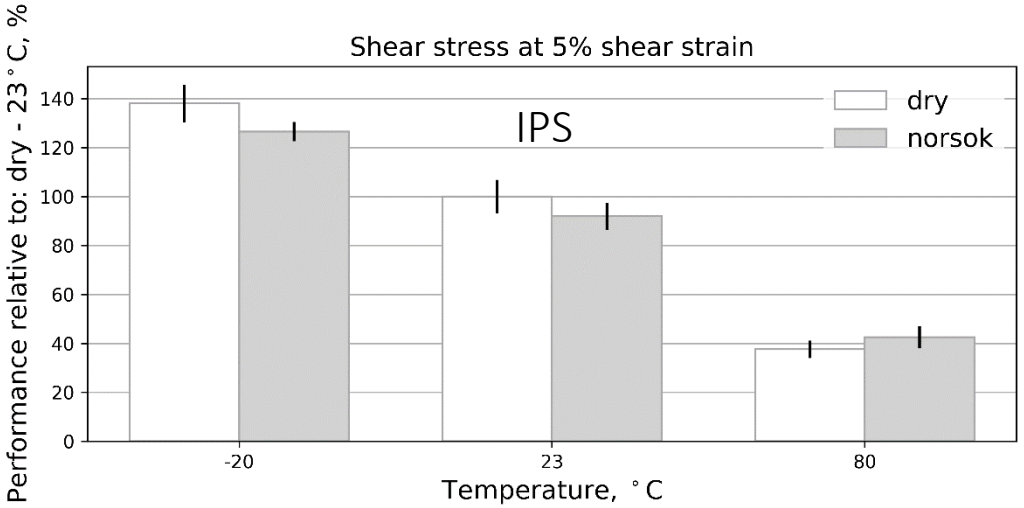
Status (1) - Static Test results (partial)









Status (2) - Test setup development

Stress rupture:

- Design and construction
- Requirements:
  - Testing in pressurized hydrocarbon environments
  - Need to test in parallel sharing heating and fluid circulation and recirculation for precise equalization of conditions
  - Stable conditions over 12,500h

Status (2) Test setup development

Fatigue:

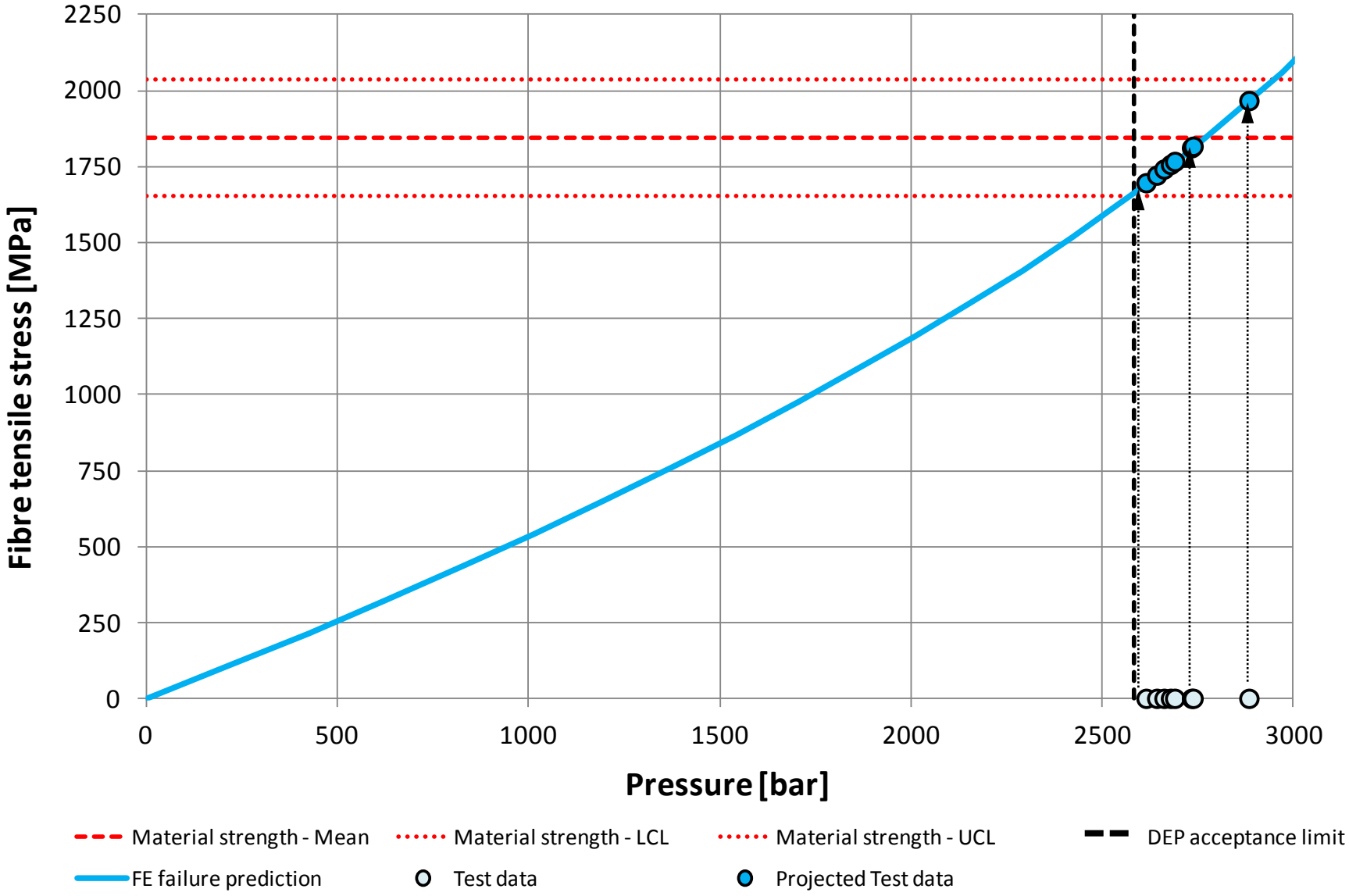
- Analogue to stress rupture fatigue setups needed to be designed to test in parallel for different failure mechanisms

Status (3) - matching model to pipe performance

Burst pressure CPA12 6” 10ksi

Procedure:

1. Material strength from coupon testing
2. FE simulation using nonlinear multi-scale material model
3. Full scale TCP burst test data
4. Project Test data on curve from FE simulation
5. Material strength as measured in full scale test



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Status (3) - matching model to pipe performance

Concluding remarks

- DNV qualification for Oil & Gas is a knowledge based-approach
- Testing focused on laminate level to limit full-scale testing
- Joint Industry Program by DNV-GL to further improve ST-F119 approach

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Thank you for your attention !

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