



Uncomfortable with uncertainty?

Structural Materials: Research for Beyond 80 Years

Session 6: Fatigue

Rockville, MD

October 2nd 2024

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The views expressed here are those of the author and do not necessarily represent those of Rolls-Royce



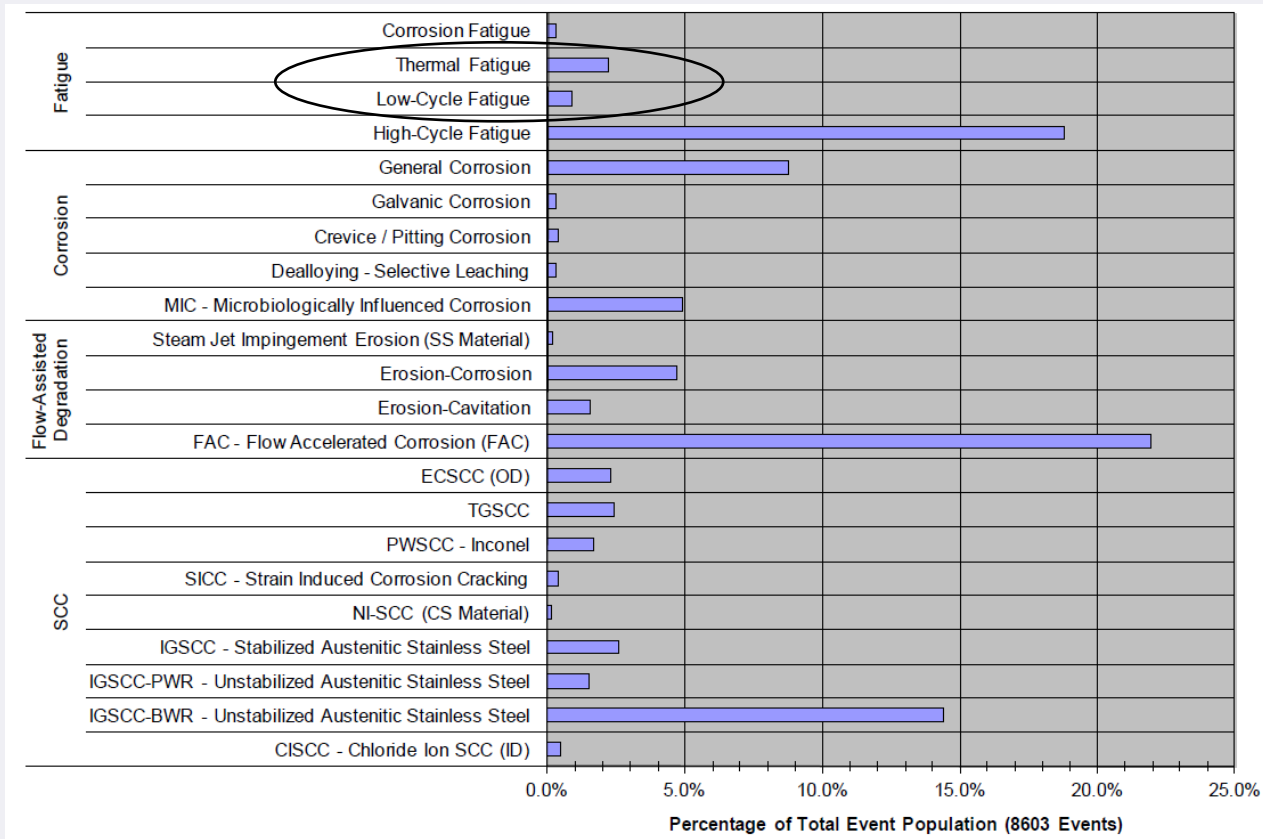
Fatigue

“The thing we put a lot of numbers to”

Relatively small contributor to experienced failures, but it’s the degradation mechanism that lends itself to calculation.

CUF = 0.99

CUF = 1.01



Data source: PIPExp database (2012)

Image source: *Pipe Rupture Frequencies for Internal Flooding Probabilistic Risk Assessments, Revision 3*. EPRI, Palo Alto, CA: 2013. 3002000079.

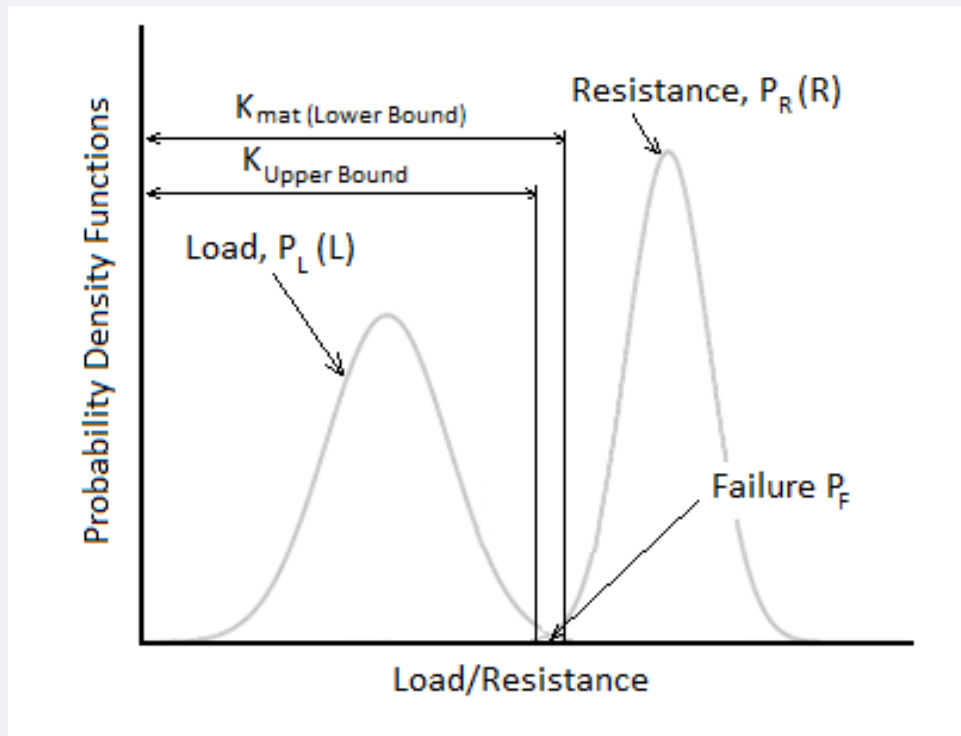
Lots of work on material resistance / behaviour

General principle of deterministic design rules:

Material resistance set to lower bounds

Factors contributing to loading terms set to upper bounds

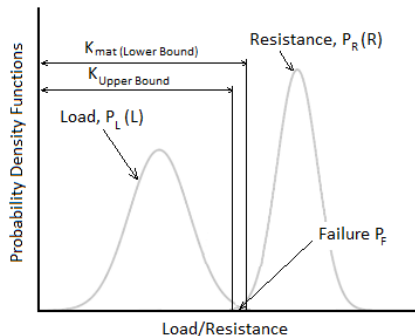
Where is the uncertainty?



Operating experience

Adverse operating experience overwhelmingly associated with loadings not considered in original design:

- Branch line thermal stratification
- Mixing tee turbulent mixing

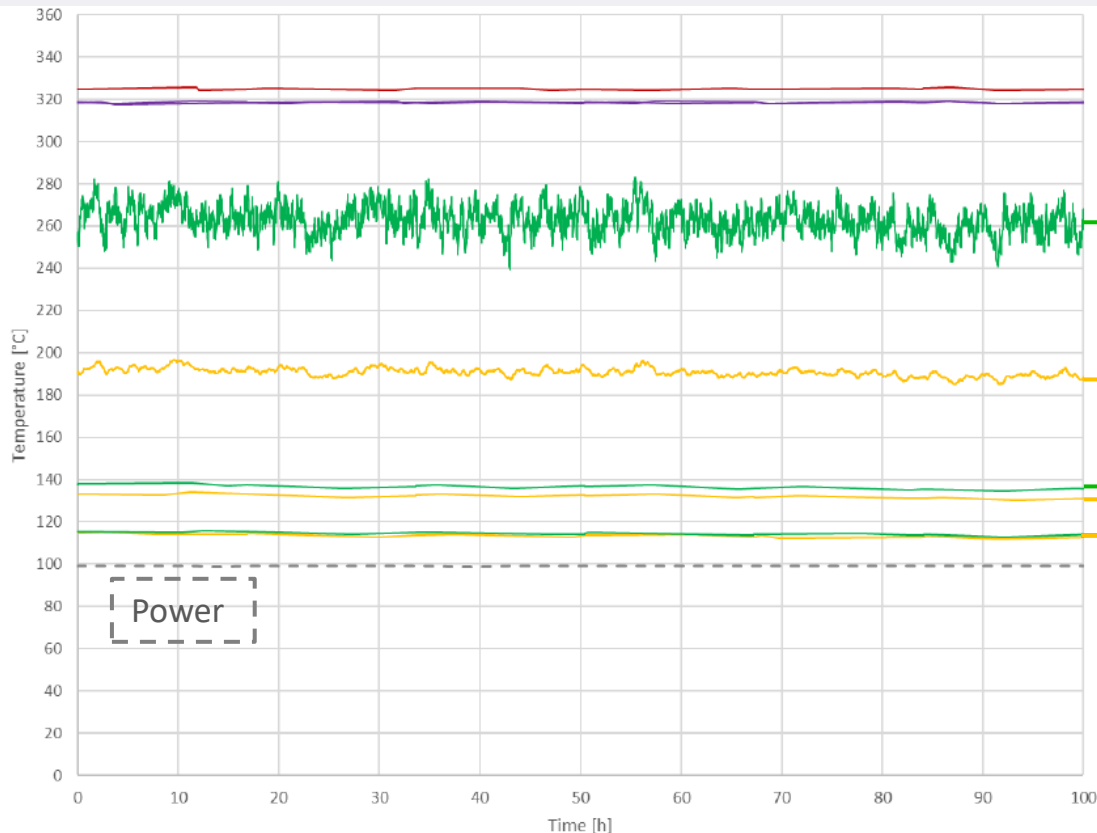
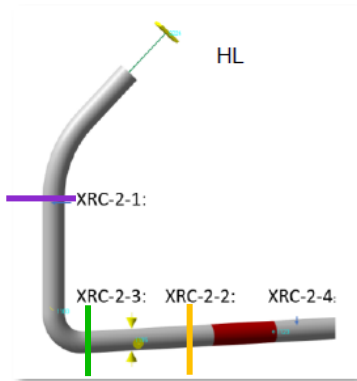


Tools to screen and evaluate these have been developed in response, but still learning.

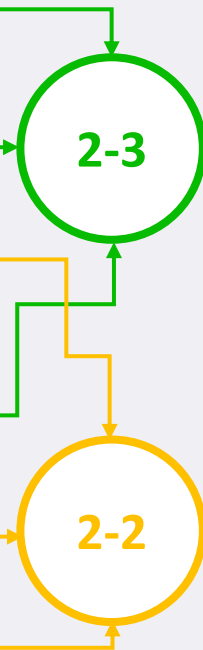


Monitoring at Ringhals 3, Sweden

Example:
R3 at FP (100%)



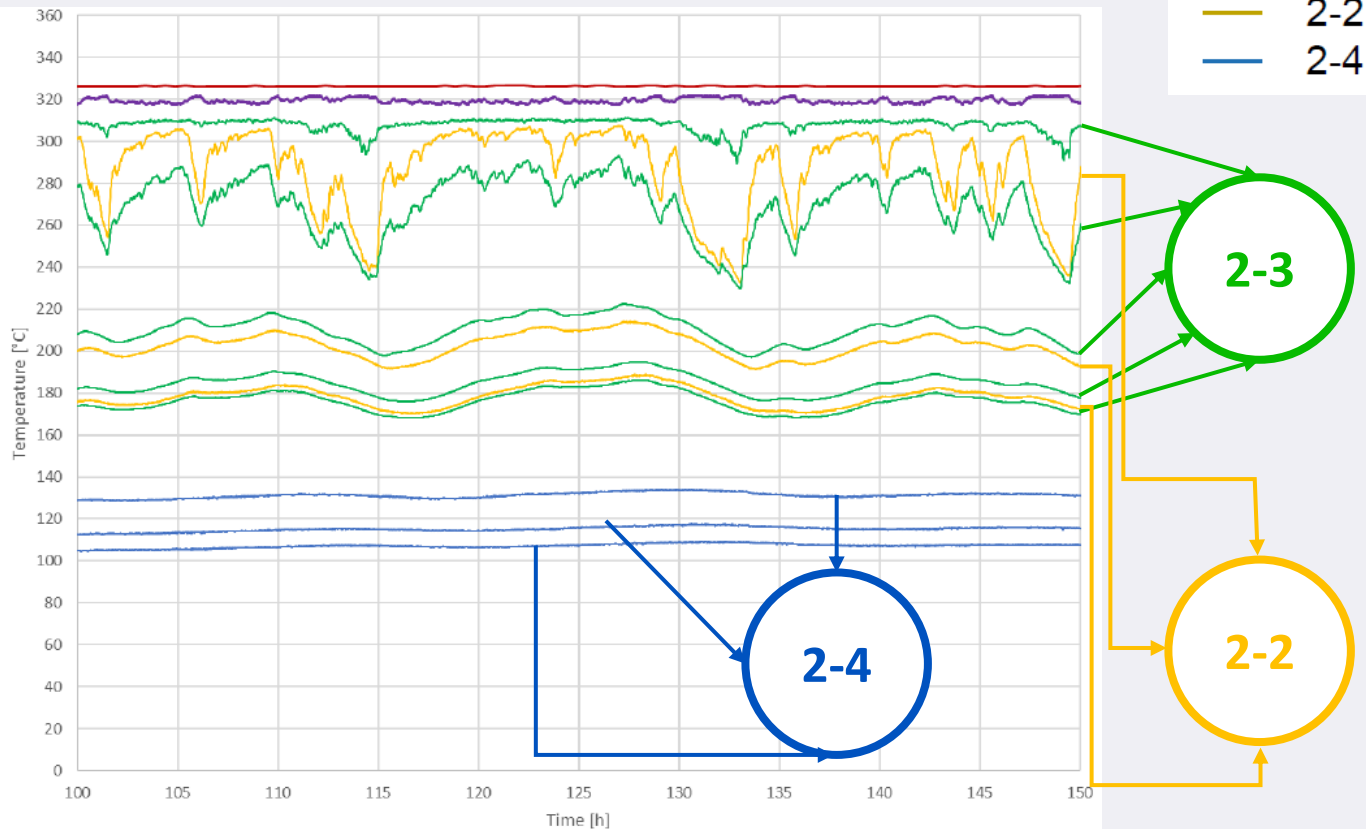
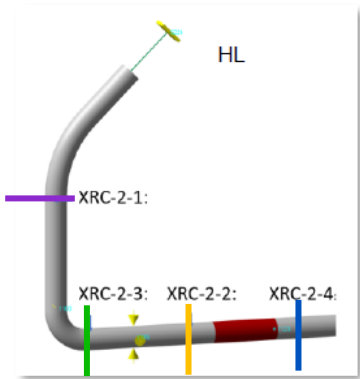
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Monitoring at Ringhals 4, Sweden

Example:
R4 at FP (100%)

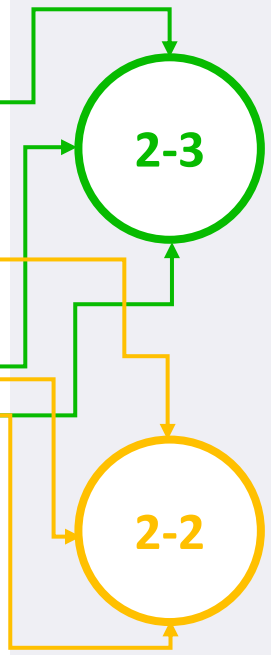
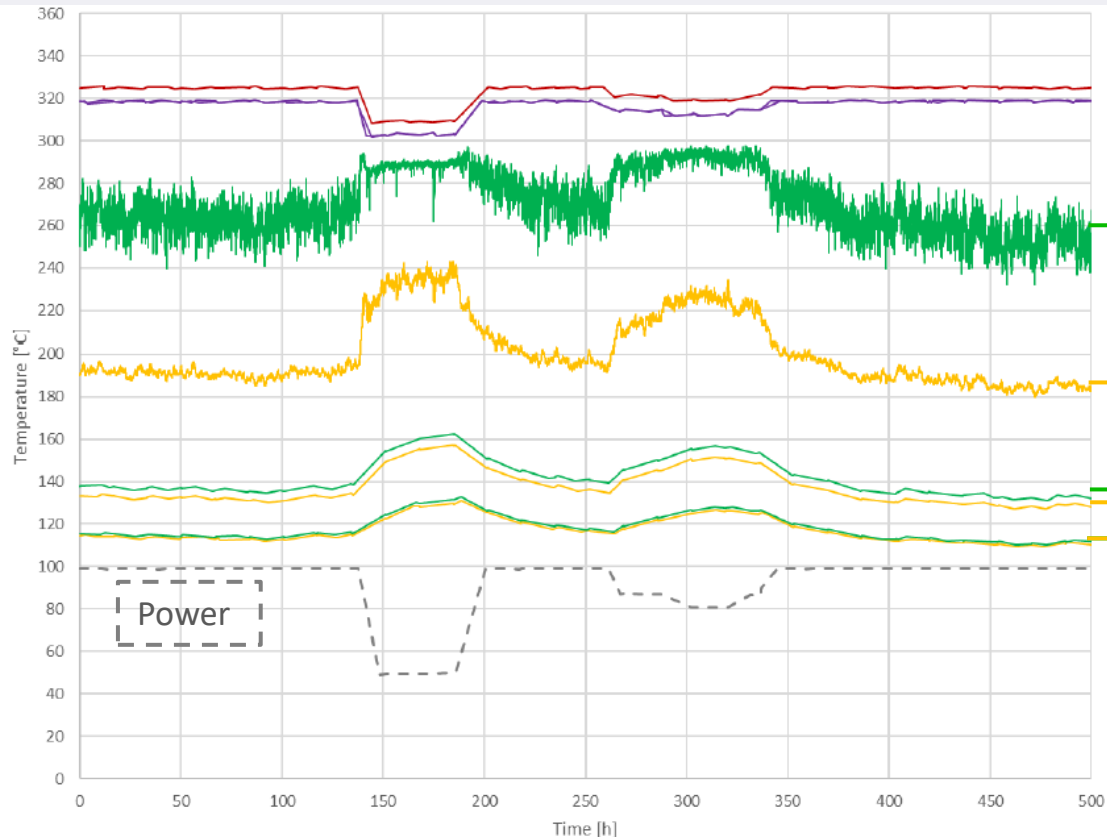
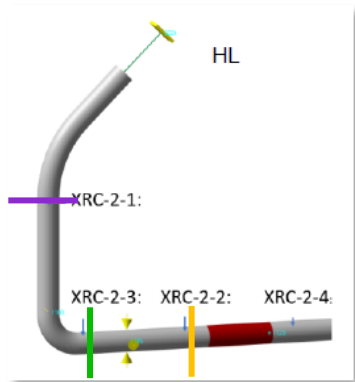




Monitoring at Ringhals 3, Sweden (Power Changes)

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Example:
R3 Power changes





R3 vs R4 an eye-opener?

Identical designs, quite different observations:

Clearly sensitive to small differences, e.g. effectiveness of insulation

Influence of power change:

Unexpected observation

Again different behaviour between nominally-identical R3 and R4 under power change (R4 power change data not shown)

Potentially important for LTO 80-plus if increasing demand for flexible operations



Power of direct measurement:

Remove uncertainty, replace ignorance/assumption with reality

Increasingly possible to handle and process large datasets, update assessments in near-real-time – common practice in some areas but limited application.

Can be risk-informed in application of this: screening tools and experience to indicate likelihood, combined with consequences either safety or economic/availability

Management – live with it or change to design/operation to eliminate.

Research areas:

Sensors / EHM / Logging / Analytics

Replacing ignorance/assumption with knowledge of reality sounds good?

Where does the reliability come from?

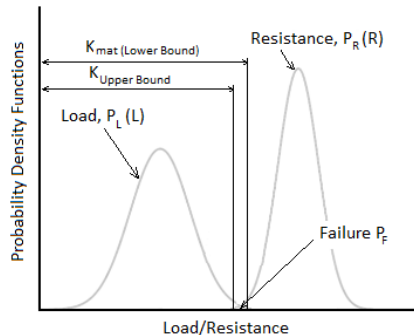
Experience to date generally very good where loading was understood despite historic issues not previously accounted for (e.g. Environmental Effect on Fatigue)

However, DFC only intends to be mildly conservative.

Acknowledges DFC is a small part of a larger whole, with a large number of conservative treatments and assumptions in the loading side (number, magnitude, order/pairing, analytical convenience)

Can't / don't codify ignorance – although present to date, will they always be?

If we “mine” all these conservatisms, where is the reliability coming from?



Take home / discussion prompt

Absolutely the right thing to do to replace ignorance with understanding.

Don't want to be unduly bound by what has been done before.

Rich vein in loading assumptions

Value of direct measurement (Ringhals observations)

However, as we attack both sides, Resistance and Load, where is the reliability?

Need to think about reliability-based methods, understanding and accounting for uncertainty.

"la connaissance progresse en integrant en elle l'incertitude, non en l'exorcisant" Edgar Morin, The Method

[“knowledge progresses by integrating uncertainty into itself, not by exorcising it”]

