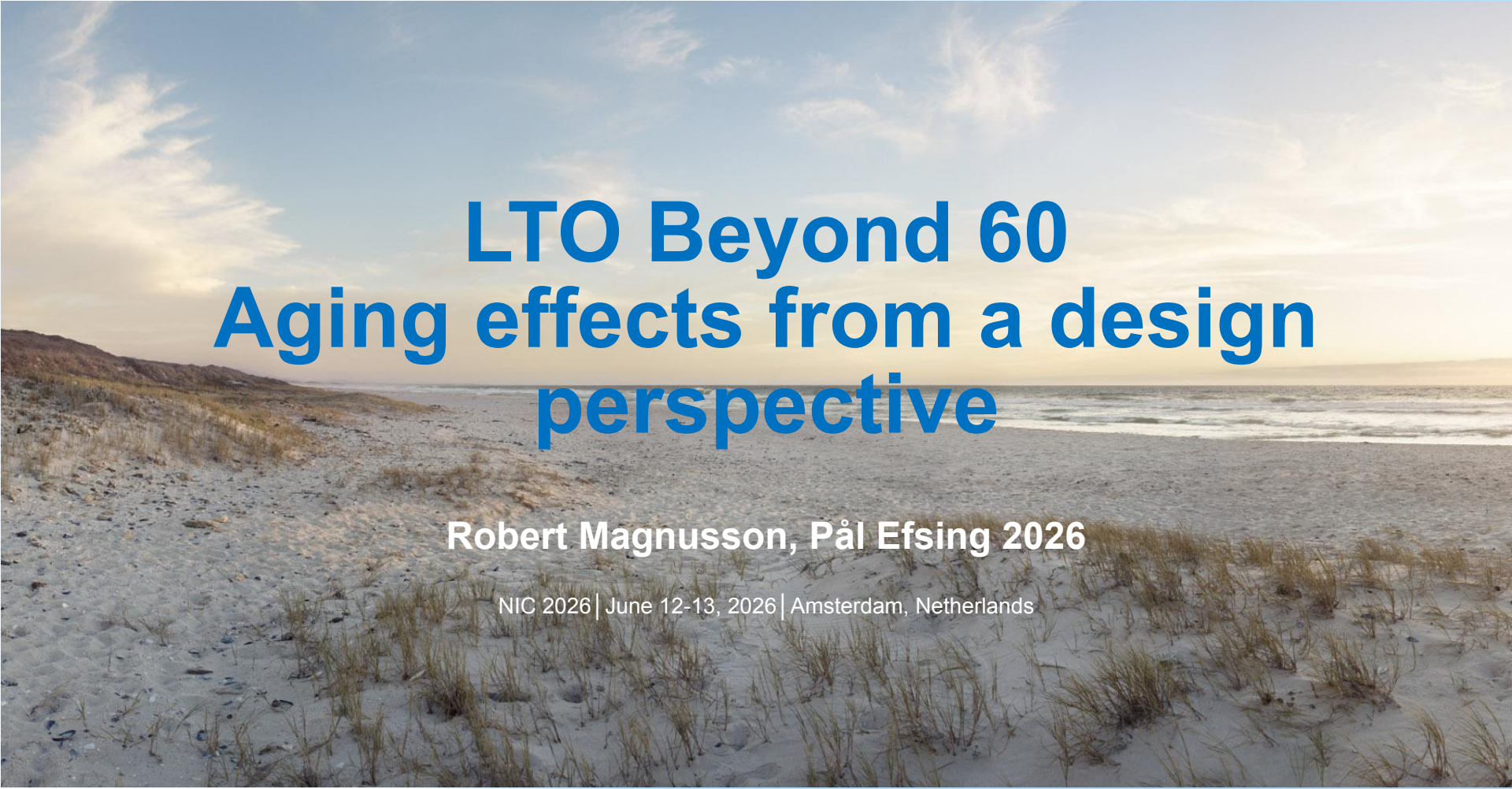

LTO Beyond 60
Aging effects from a design perspective

Robert Magnusson, Pål Efsing 2026

NIC 2026 | June 12-13, 2026 | Amsterdam, Netherlands

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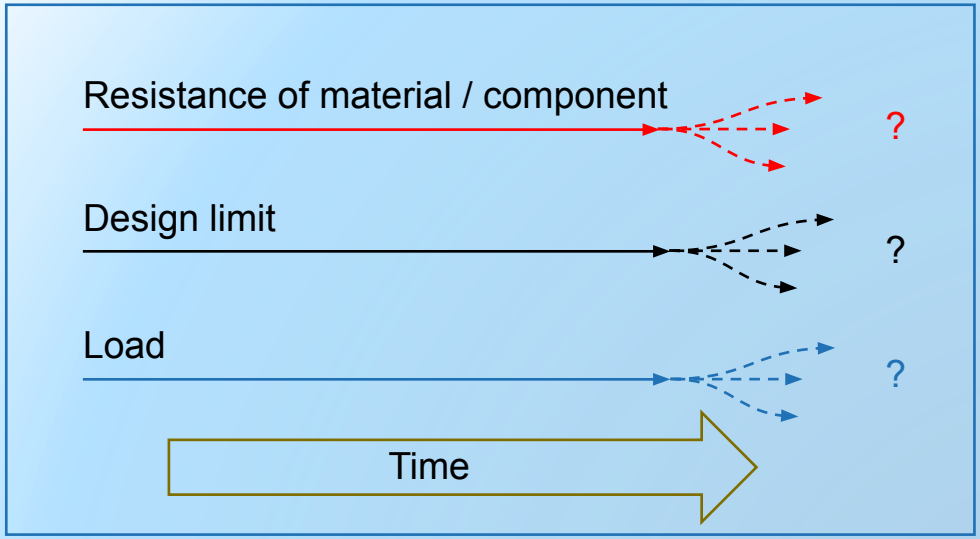
Introduction

Agenda:

Connecting aging effects with loads and design limits

1. Introduction Ringhals
2. Ringhals roadmap 60+
3. Aging and design considerations
4. Conclusions



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Introduction Ringhals

Ringhals 1 (R1)
BWR, ASEA ATOM
Commercial operation 1976
Shut down 2020

Ringhals 2 (R2)
PWR, Westinghouse
Commercial operation 1975
Shut down 2019

Ringhals 3 (R3)
PWR, Westinghouse
Commercial operation 1981
Planned service life 60 years
Investigation of 80 years

Ringhals 4 (R4)
PWR, Westinghouse
Commercial operation 1983
Planned service life 60 years
Investigation of 80 years

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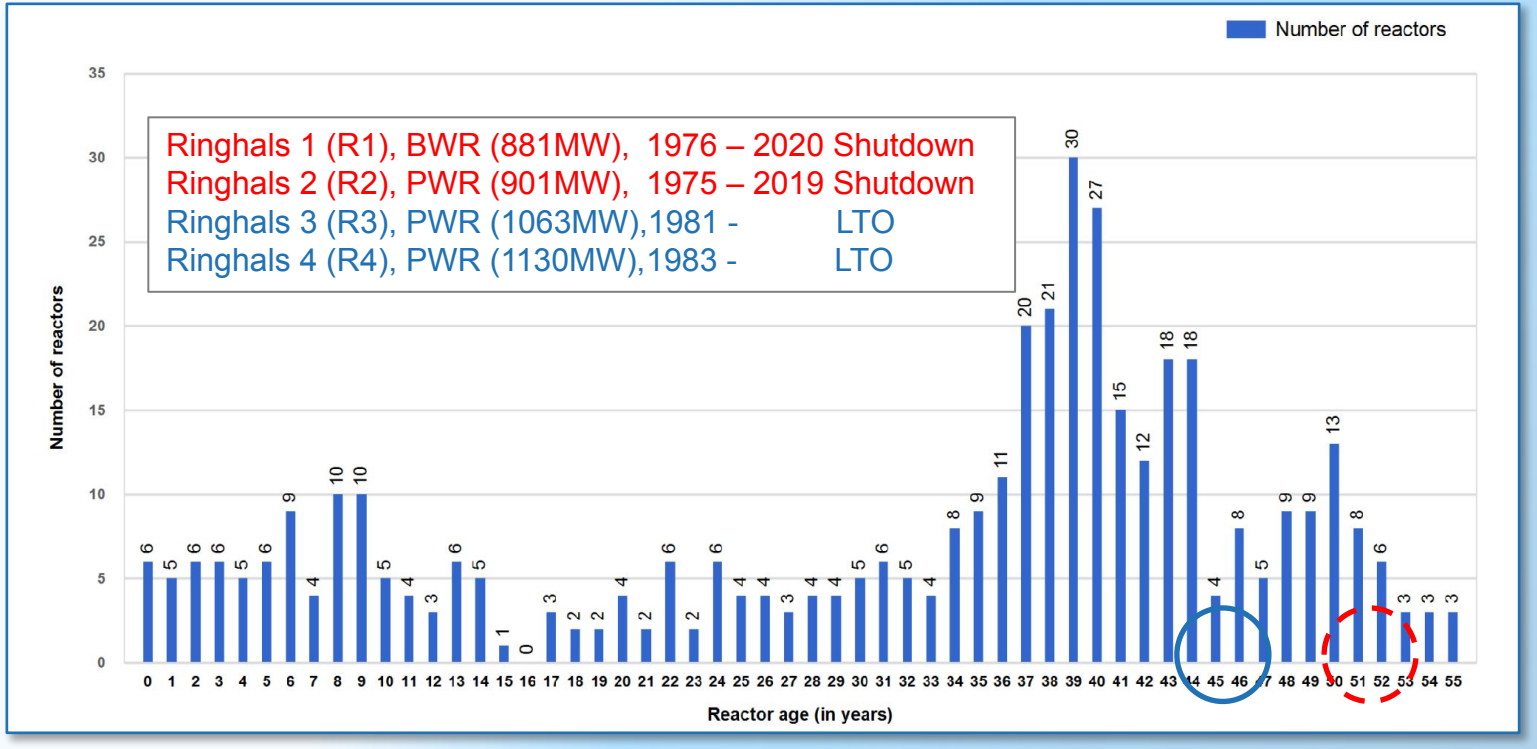
Introduction Ringhals



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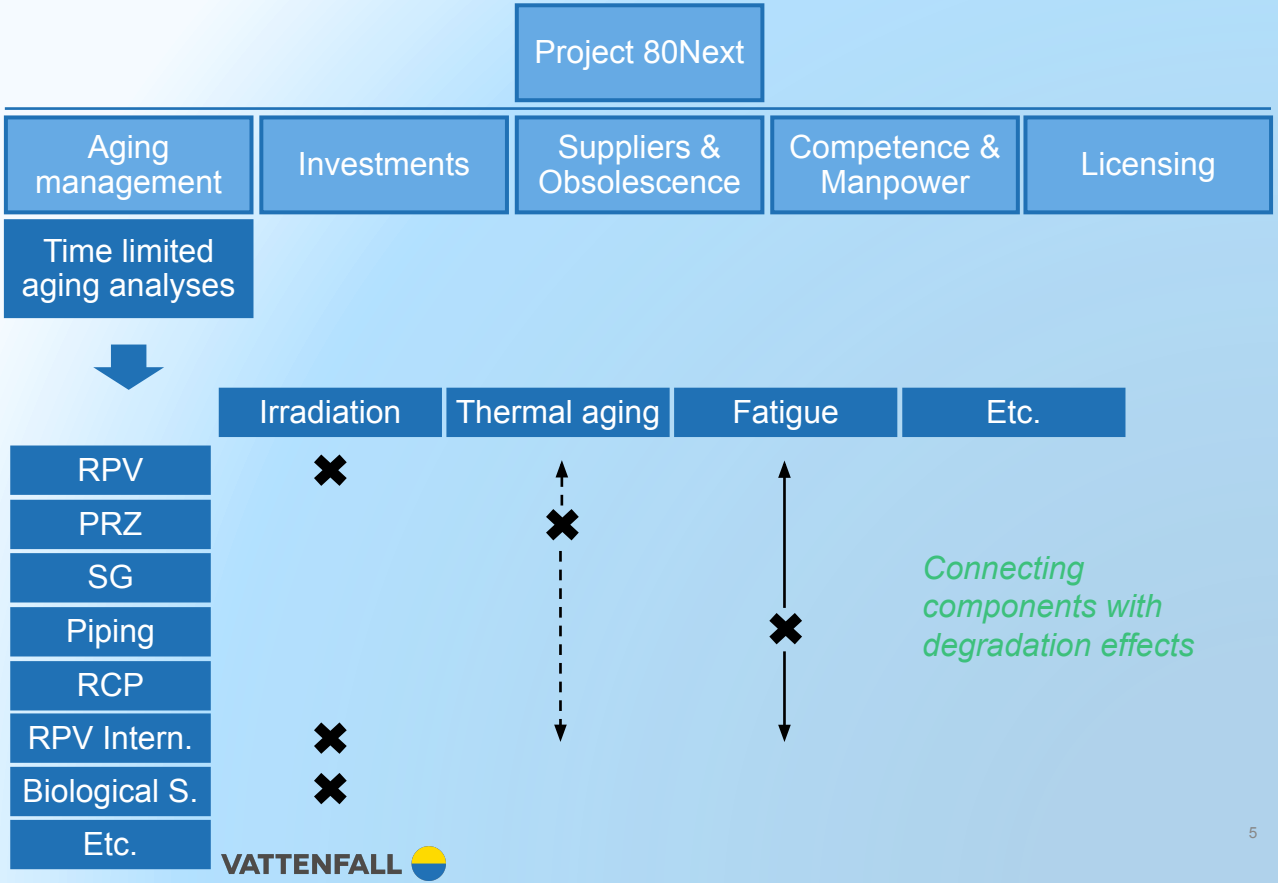
Ringhals roadmap 60+

2023–2026: Vattenfall project 80Next evaluating 80-years of operational lifetime.

Conclusion: The project demonstrates that 80-years of operation is feasible. However, certain areas require focused attention.



Ringhals roadmap 60+

2023–2026: Vattenfall project 80Next evaluating 80-years of operational lifetime.

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Project 80Next

Aging management	Investments	Suppliers & Obsolescence	Competence & Manpower	Licensing

Time limited aging analyses

Irradiation	Thermal aging	Fatigue	Etc.

- RPV
- PRZ
- SG
- Piping
- RCP
- RPV Intern.
- Biological S.
- Etc.

Aging impacts material / component resistance
- Microstructural changes
- Reduced toughness
- Hardening (higher strength, lower ductility)
- Local stress concentrations
- Irreversible damage in the microstructure

The magnitude and duration of loads together with number of transients:
- Affects the extent of aging
- Influences the safety margins to failure

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Ringhals roadmap 60+

Ringhals activities to understand design limits in a 60+ perspective

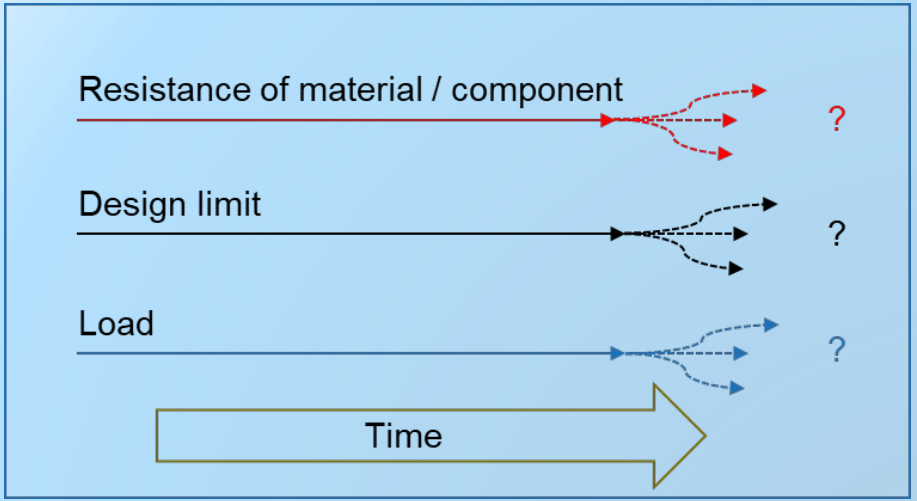
Testing of aged materials and components:

- R&D Projects (e.g., EPRI, SMILE).
- R&D Internal Projects (Fatigue, Thermal Aging).

Optimizing load conditions:

- Operational changes (frequency, temperature, rate).
- Monitoring and characterization of transients.
- Mitigation (e.g., Shielding, Temperature).

Discussion about design limits (framework) with respect to statistics, conservatisms etc.



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Aging and design considerations

R&D to support the management of aging effects

Improve understanding of aging effects on materials:

- Joint research on materials harvested from Ringhals 1 and 2.
- Mechanical testing and microscopy studies of aged materials.

Harvesting of materials

- Ringhals 1 and 2 were in commercial operation from 1975–1976 until 2019–2020.
- Harvested components from RPV, Internals, Piping etc.

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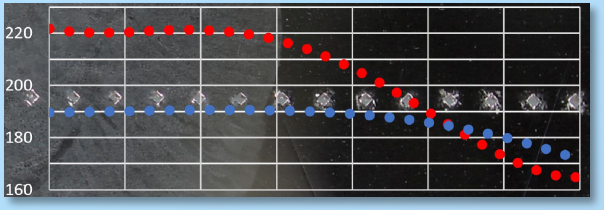
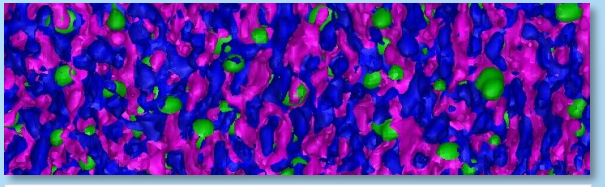
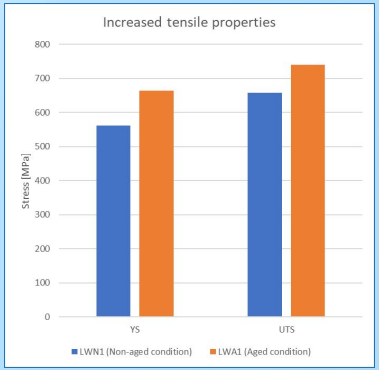
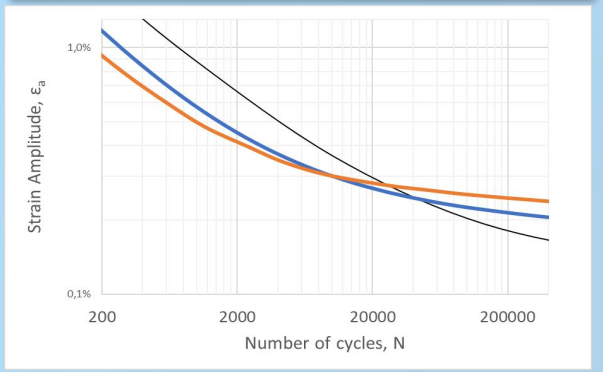
Measurements in lab indicates aging effects









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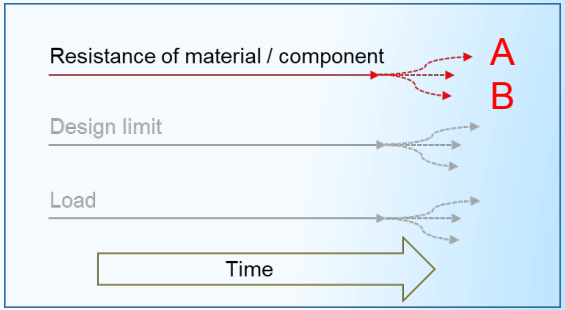

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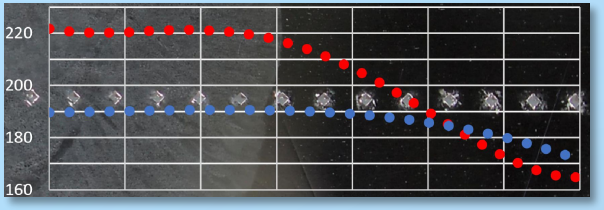

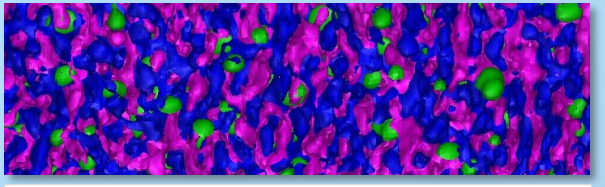

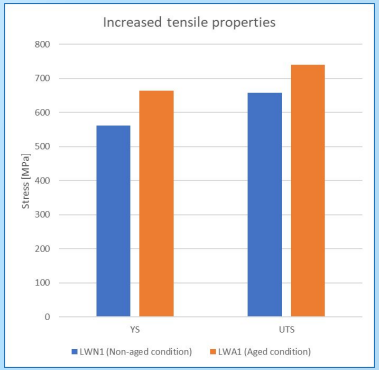

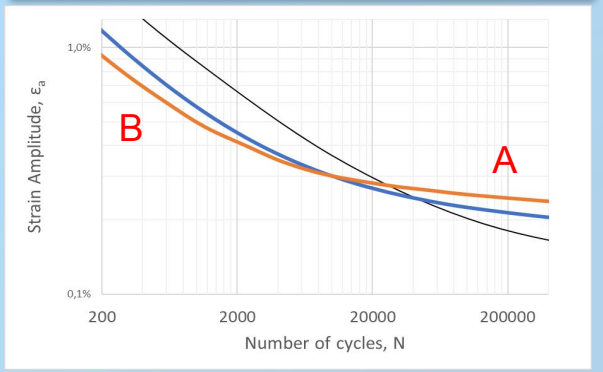

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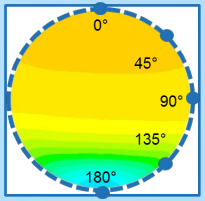
Aging and design considerations

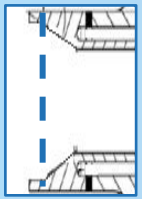
R&D to support the management of aging effects

Improve understanding of load conditions and of how to measure and characterize transients:

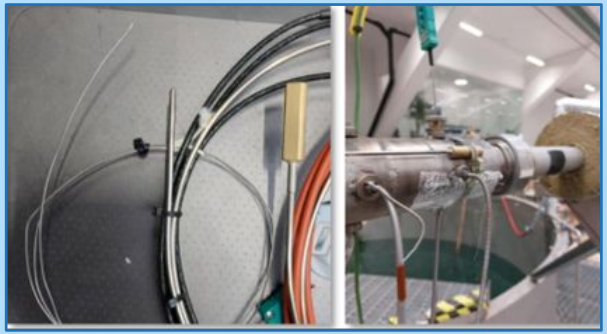
- Evaluating different types of sensors.
- Evaluating different types of phenomena and analysis models.

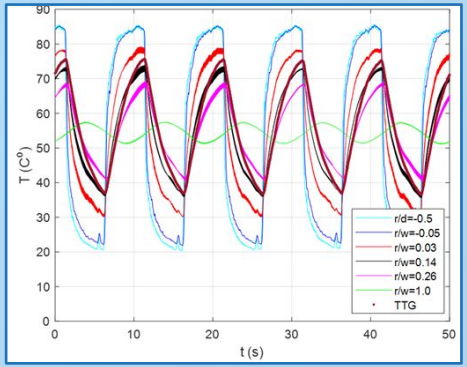
Measurements in plant





Measurements in lab





Resolution is dependent on sensor

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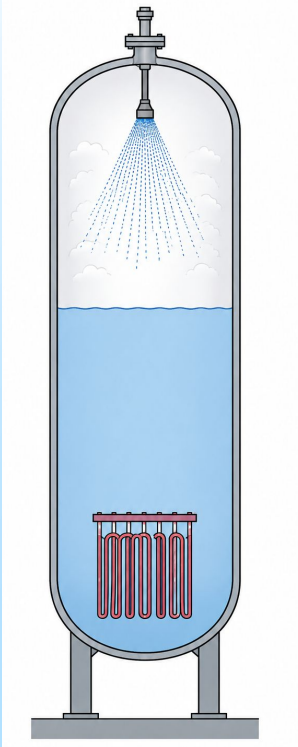

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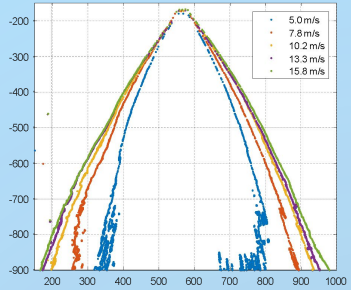
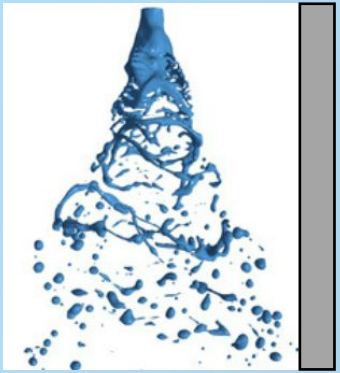


Evaluating phenomena



Evaluation of:

- Droplets hitting the wall.
- Cooling effect on wall.
- Resulting strain and stress.

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Aging and design considerations

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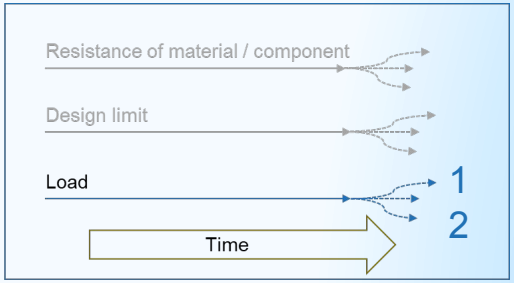
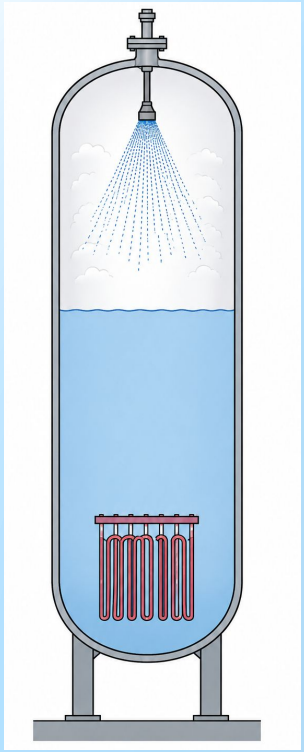
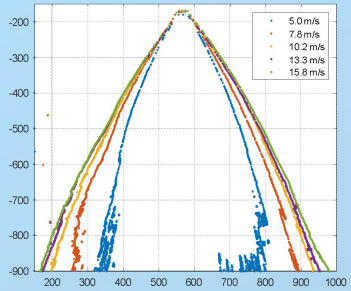




Measurements in lab



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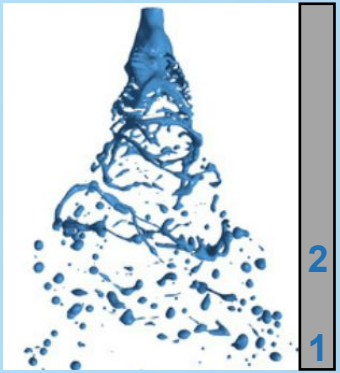

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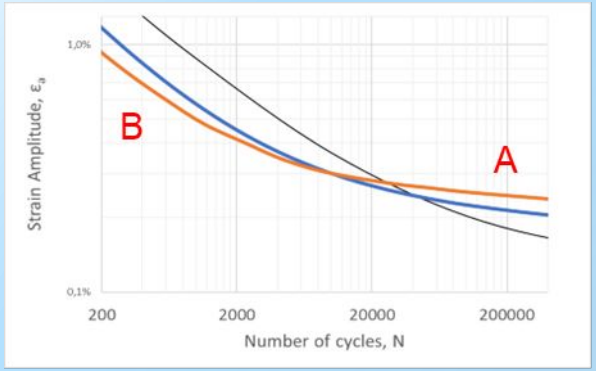
Conclusions

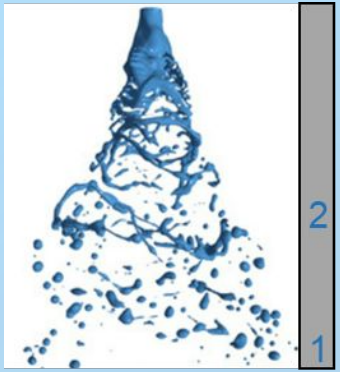
Ringhals R&D activities to understand design limits in a 60+ perspective

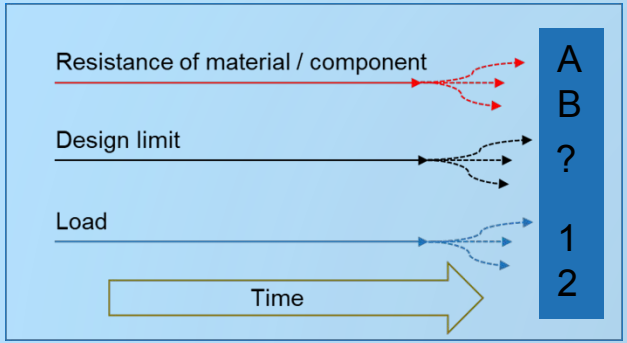
Improved understanding of aging effects and material resistance, together with better knowledge of actual load conditions, may enable extension of component design life.

Evaluation of design limits in aging components is complex, as results may vary depending on load conditions and location.

Connecting aging effects with loads and design limits enables improved identification of critical locations and stronger decision-making for operation beyond 60 years.







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Thank you!