Challenges for LTO beyond 60 years

OPEX from Vattenfall

Containment steel liner and aging of reactor pressure vessel

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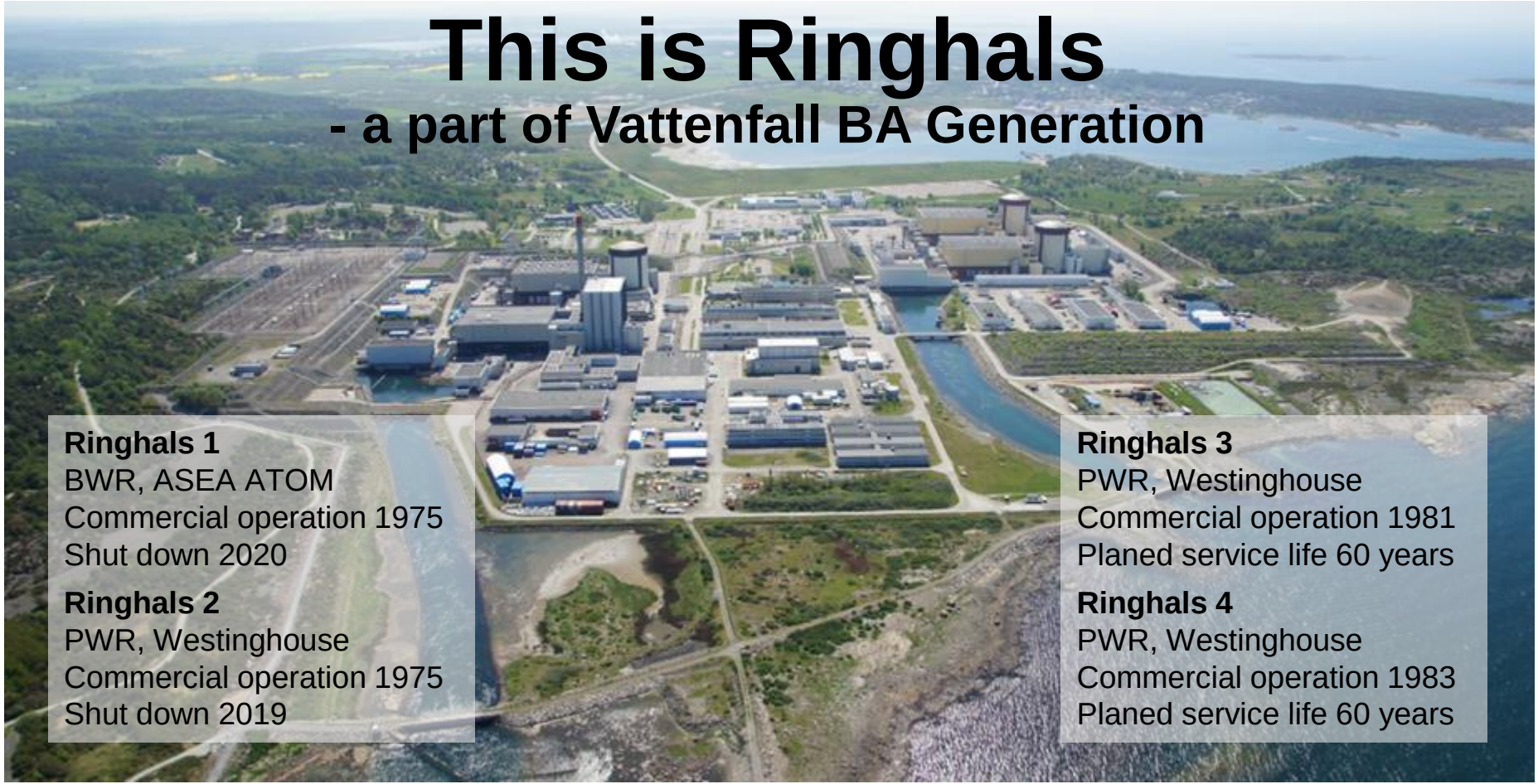
Agenda

- Ringhals NPP
- Containment steel liner
- Primary components

This is Ringhals

- a part of Vattenfall BA Generation



Ringhals 1
BWR, ASEA ATOM
Commercial operation 1975
Shut down 2020

Ringhals 2
PWR, Westinghouse
Commercial operation 1975
Shut down 2019

Ringhals 3
PWR, Westinghouse
Commercial operation 1981
Planed service life 60 years

Ringhals 4
PWR, Westinghouse
Commercial operation 1983
Planed service life 60 years

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Containment steel liner

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Containment steel liner
– a critical part for LTO?

Three different cases appearing after around 40 years.

Unit 3 – embedded liner in containment wall

Unit 2 – containment bottom plate

Unit 1 – visible steel liner

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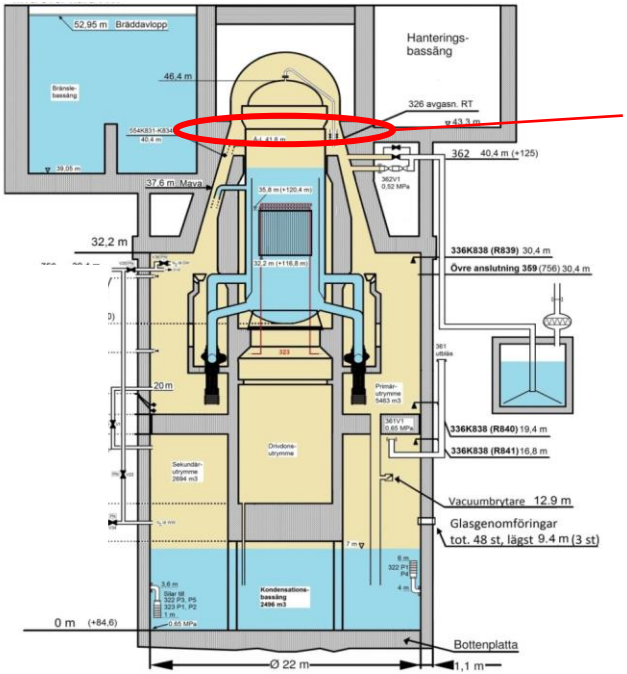
Ringhals 1, leakage found after CAT 2017

- Inspection after CAT found a water drip
- 3 holes were found
- Wet insulation
- Liner replaced



Effected area

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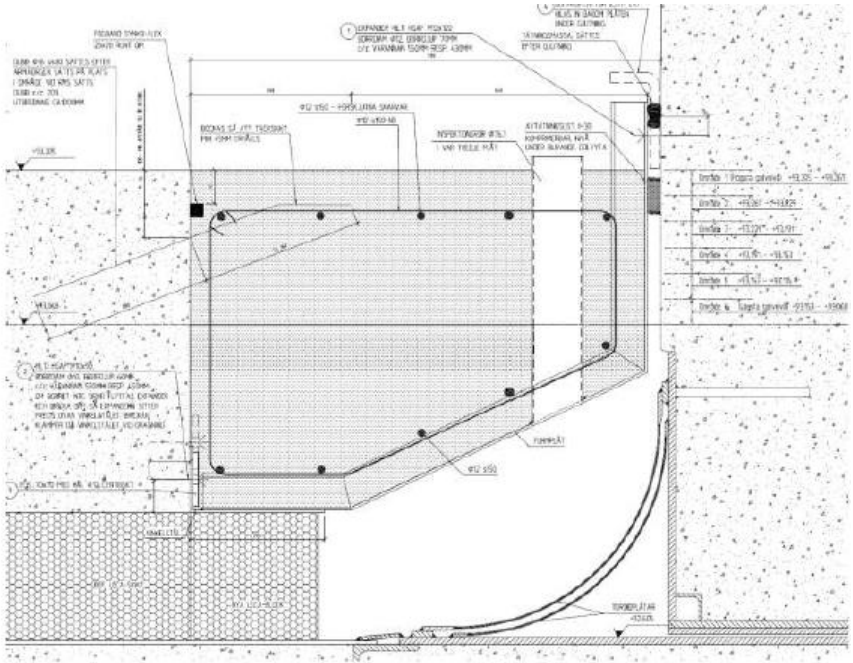
Ringhals 2, leakage through toroid and bottom plate

- Unique construction
- Leakage through toroid 2005
  - Exchange of both toroids
- Increased leakage of water during CAT 2014
  - Damage since toroid replacement 2005
  - Other corrosion were found as well



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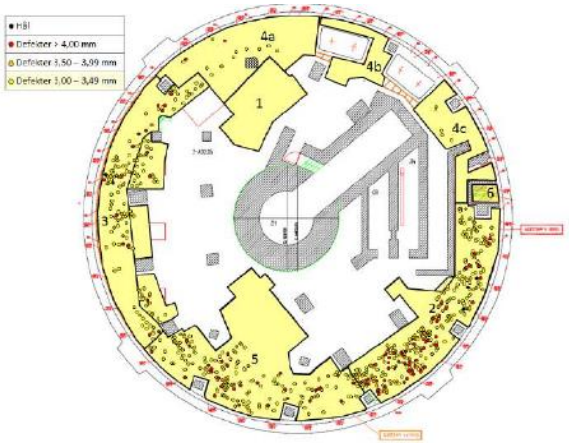
Ringhals 2, leakage through toroid and bottom plate



- Drilling damage
- Other type of corrosion
- Inspected areas

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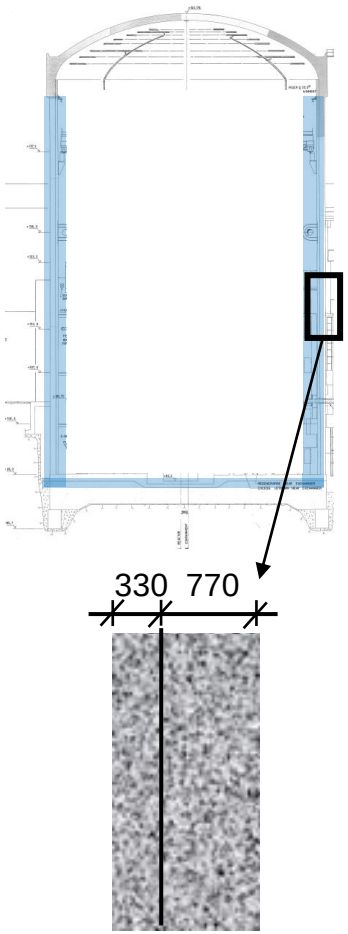
Ringhals 3

Construction of Swedish containments

- The construction of containments in Sweden differs from other countries. The larger parts of the liner is embedded in concrete (blue parts in the figure)
- The wall consists of (from inside and out)
  - 330 mm reinforced concrete
  - 8-10 mm liner
  - 770 mm post-tensioned concrete
- Only verification test is the containment integrity test. The liner is not possible to inspect.



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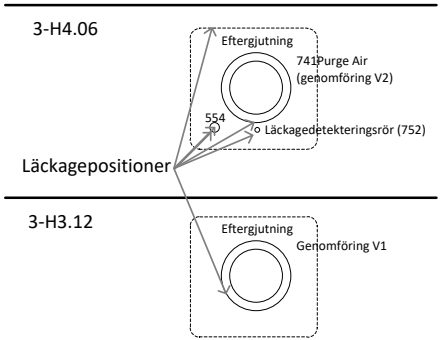
Containment liner corrosion

- During the ILRT of Unit 3 in 2016 a local leakage was found during the inspection of areas around penetrations.
- A safety assessment was done with the conclusion that it was safe to operate the reactor until the next outage.
- The local leakage was from an area where the liner is embedded in concrete and therefore not possible to inspect.



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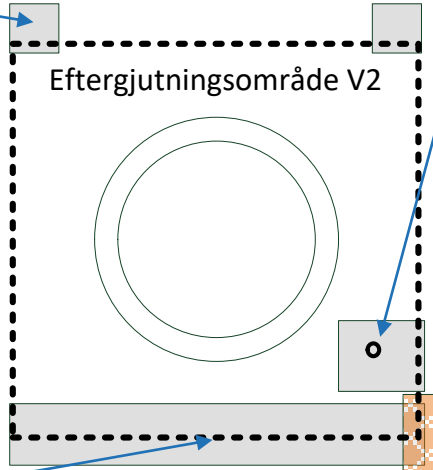
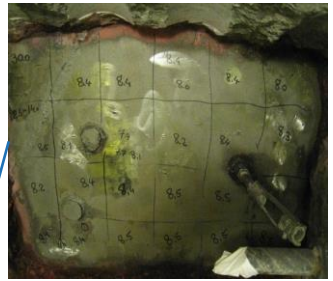
Containment liner corrosion

2018





2017

2018

2020

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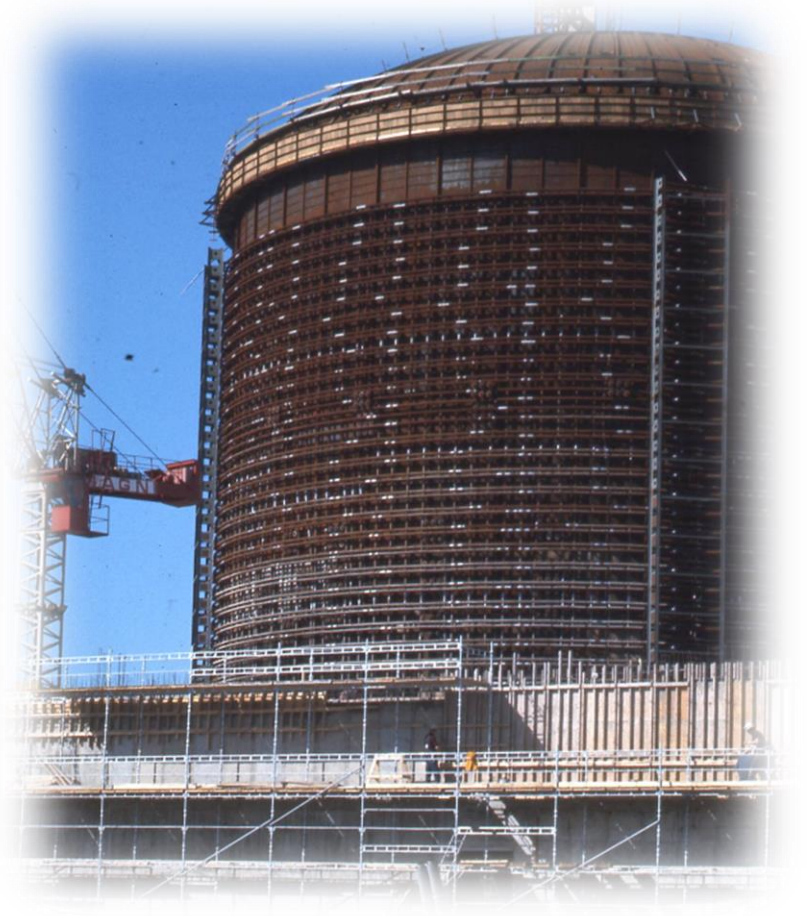
Conclusions

Containment steel liner – a critical part for LTO?

New issues may appear with time.

May take time – but, so far, possible to solve.

NDT Embedded liner



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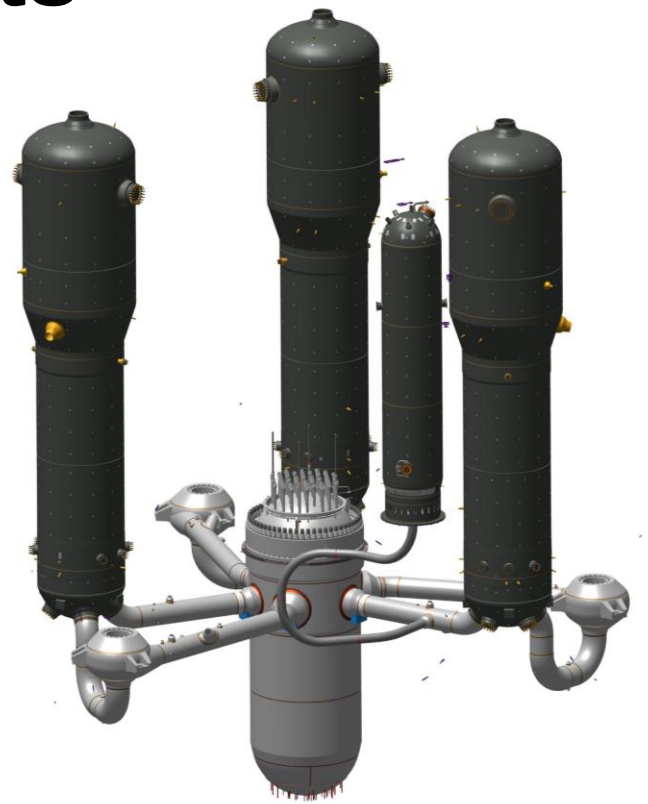
Primary components

Challenges/Focus areas at Ringhals

- Reactor Pressure Vessel
- Reactor Vessel Internals
- Pressurizer
- Steam Generator
- Piping



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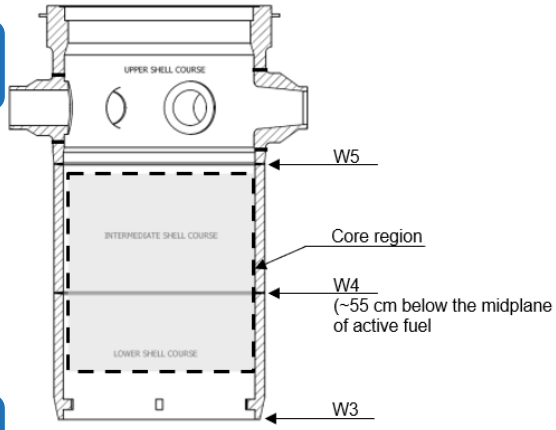
Reactor Pressure Vessel

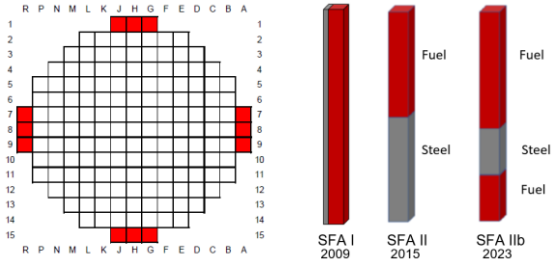
RPV beltline weld limiting material for operation

- Most Swedish NPP's primary components were manufacturing by the Swedish company Uddcomb and their signature weld metal with high Nickel (~1.6 wt %) and Manganese (~1.5 wt %) content.
- Almost linear Embrittlement Trend Curve - Limited saturation
- Under-predicted by most internationally accepted ETC's



Unit 3 beltline weld limiting fracture toughness

- Deterministic PTS analysis is the limiting analysis
- Valid for 60 years of operation
- Shielded Fueling Assemblies necessary for LTO
  - First generation installed 2009 – SFA I
  - Third generation installed on Unit 3 in 2023 – SFA Iib



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Reactor Pressure Vessel

Ongoing projects

Surveillance program

- All surveillance capsules are removed, fluence envelop 60 years of operation and more
- Surveillance program based on verifying fluence according to external dosimetry program (Installed 2008)

Increasing the safety margins (PTS-transient)

- To get a better understanding of the inherent margins and get additional margins to conclude a robust vessel design for 60 years and more, further assessments is required, e.g.:
  - Validation of constraint effect
  - Analytical crack arrest analysis

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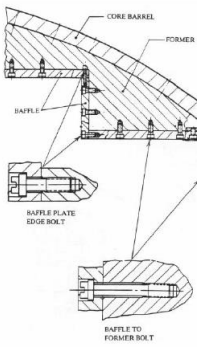
Reactor Vessel Internals

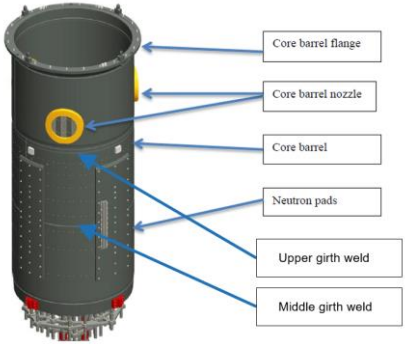
Baffle to Former Bolts

- NDE: 100 % UT every 10th, with a 5-year offset – no indications detected
  - Unit 3 is Upflow converted in 2020 last inspected in 2016
  - Unit 4 is by design Upflow with cooling holes for bolts
  - Westinghouse Baffle Former Bolt Acceptable Bolting Pattern Analysis (ABPA) - Demonstrates acceptability of reduced baffle-former bolting



Core Barrel Weld

- NDE: Historically, primary focus on middle grith weld – (belt line weld highly irradiated)
- Upcoming examinations will focus on both inside and outside surface of accessible welds - due to operating experience in U.S. and changes in industry recommendation
- Follow the lates EPRI recommendations regarding fracture toughness data and flaw evaluation
  - Equivalent weld material from Unit 2 has been harvested, 29.7 EFPY up to 5 dpa, and will be tested within the SMILE-project starting autumn 2024



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Pressurizer

Thermal Ageing of LAS Weld Metal

- Same type of weld metal as for the RPV:s – high Ni and Mn
  - Unit 4 PRZ replaced in 2011
  - Unit 3 original PRZ in operation challenge to validate the PRZ for 60+ years of operation
- Project started to investigate the impact of thermal aging of unit 4 PRZ base metal, HAZ and welds
- Material testing from unit 4 PRZ and unit 2 PRZ, aged for 215 000h and 295 000h, respectively
  - Limited thermal ageing were observed in base metal and HAZ for unit 4 PRZ
  - The weld metal exhibits a significant loss of fracture toughness and a potential hardening effect, with a high shift in ductile-to-brittle transition temperature (80 °C for unit 4 and 125 °C for unit 2)
- Ongoing project aiming understanding the degradation mechanisms and develop an Embrittlement Trend Curve for thermal aging

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Steam Generators

Corrosion Products

- Transport of corrosion products and other impurities that contributes to deposits and the formation of hard sludge on tubes, tube sheet and internal structures have been identified as the main technical issue for the SG.

Transients

- Thermal transients on secondary side nozzles have been evaluated and are discussed in the 60+ frame.

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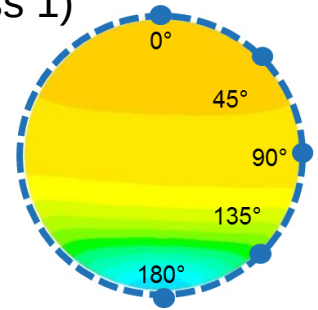
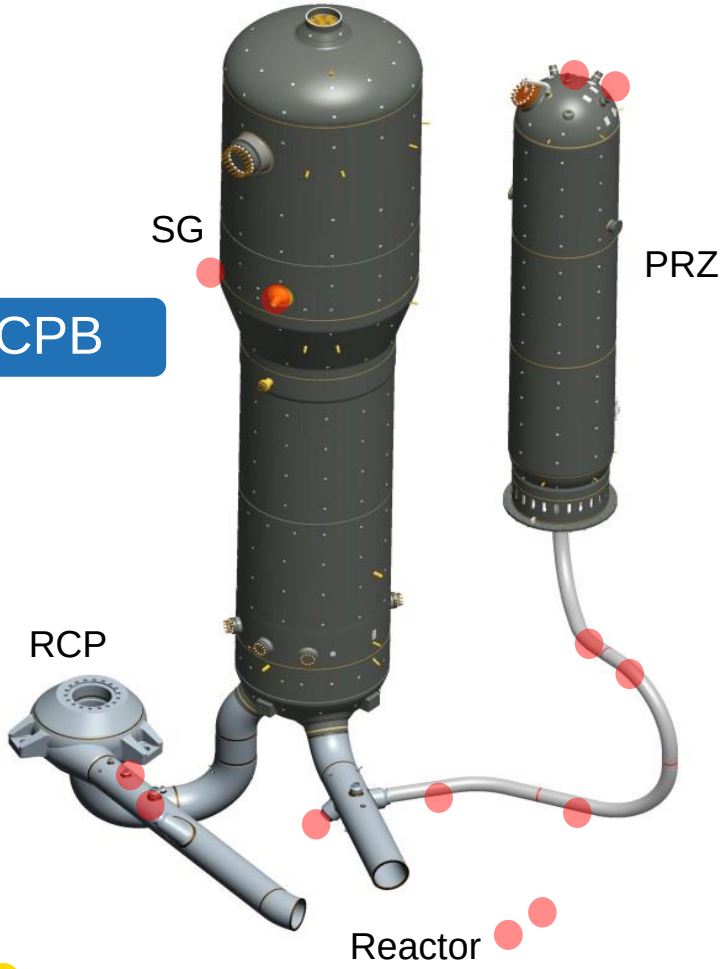
Piping

Campaign to monitor conditions in RCPB

- Positions based on:
- System temperature differences (ΔT)
  Margins in our design analyses (CUF)
  Operational experience (external/internal)
- Priority is RCPB (Class 1)





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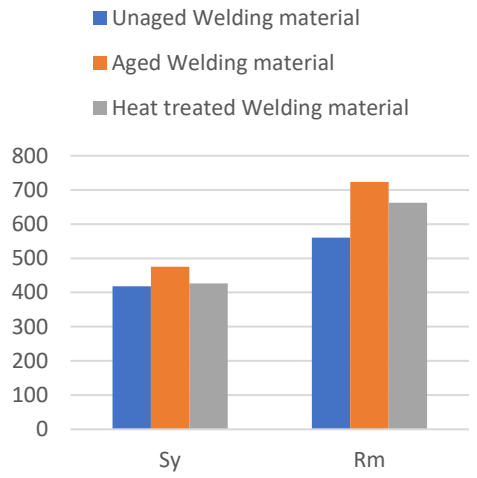
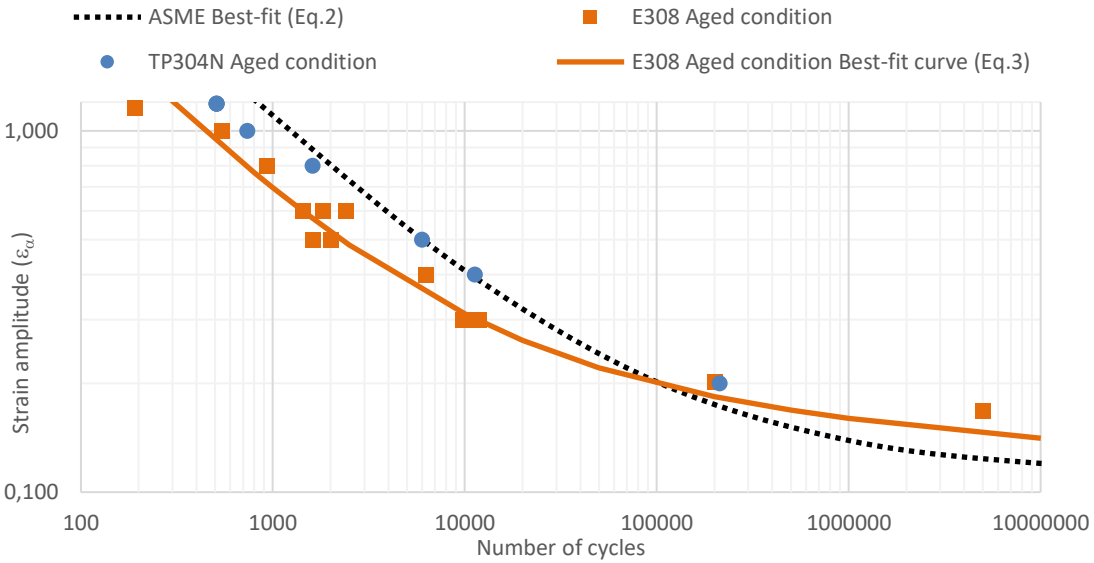
Piping

Investigating material and fatigue properties in aged condition

E.g: Stainless steel welding and base material from Surge Line investigated.

- Aged in 345 °C for 30 years





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