

Operating Experience from Early-Stage Nuclear Plant Failures

June 2026



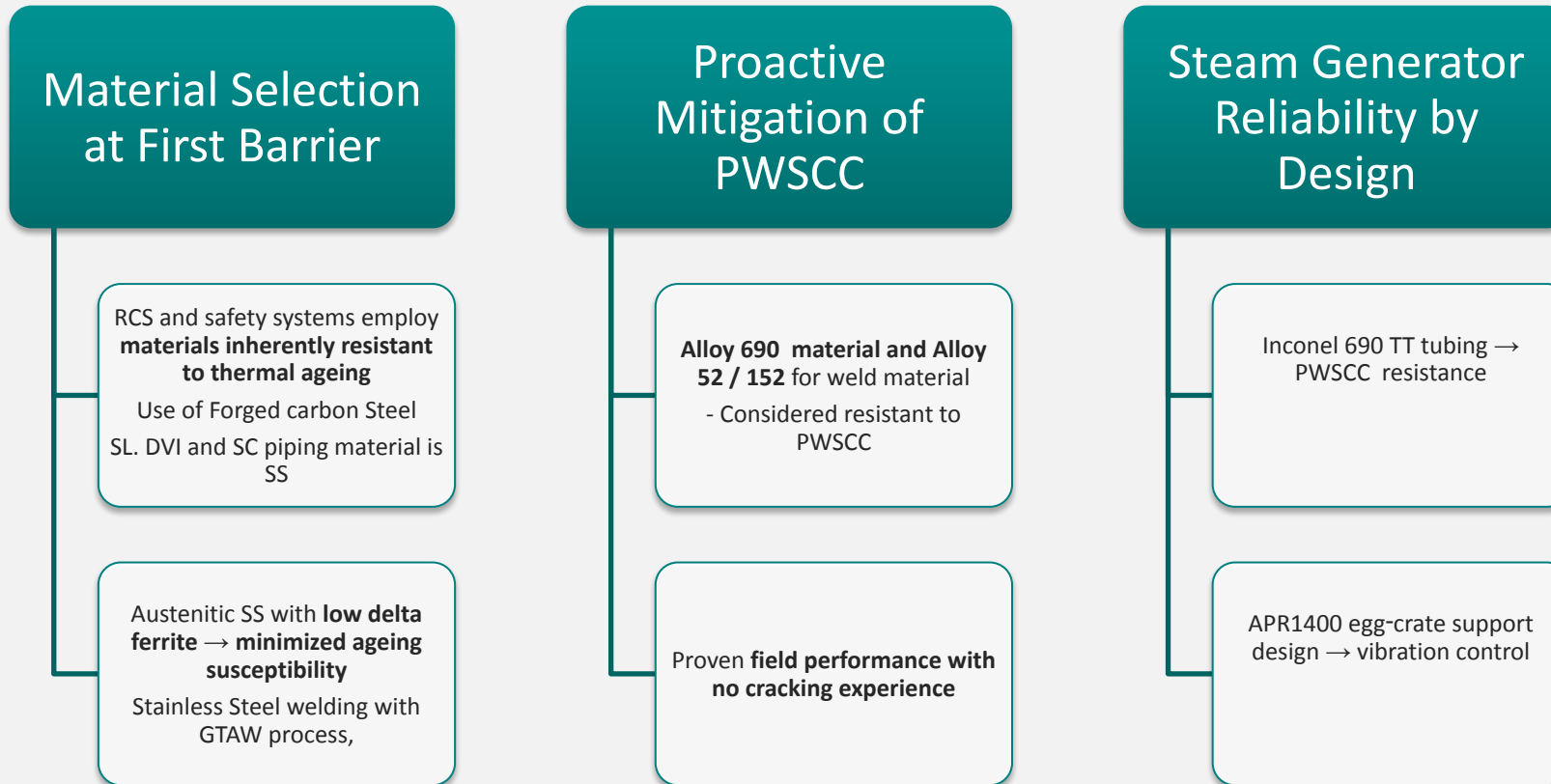
BNPP IAMP Presentation Content

- Applying Lesson Learned during Design Phase
- Applying Lesson Learned during Construction & Commissioning Phase
- Applying Lesson Learned during Operation Phase
- Pressurizer Heater
- Feed Water Heater 5B
- Socket Welds
- Essential Service Water Piping
- Stainless Steel Liner Plate



Aging Management throughout the NPP lifetime

Applying Lessons learnt and Aging Management during the Design phase:



Ageing is not managed later – it is engineered out at the design stage

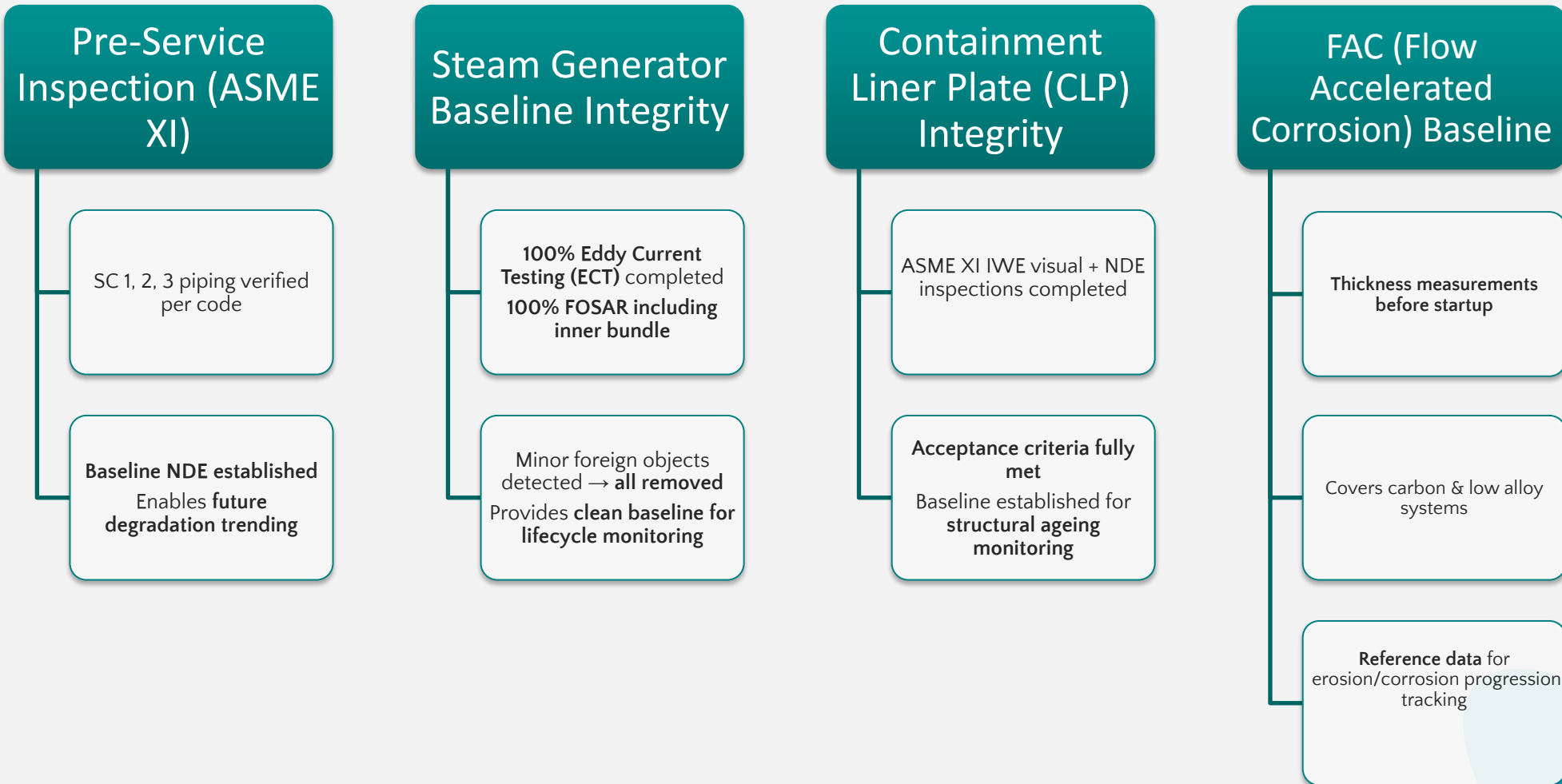


Aging Management throughout the NPP lifetime

Applying Lesson Learnt & Ageing Management during Construction & Commissioning phase:



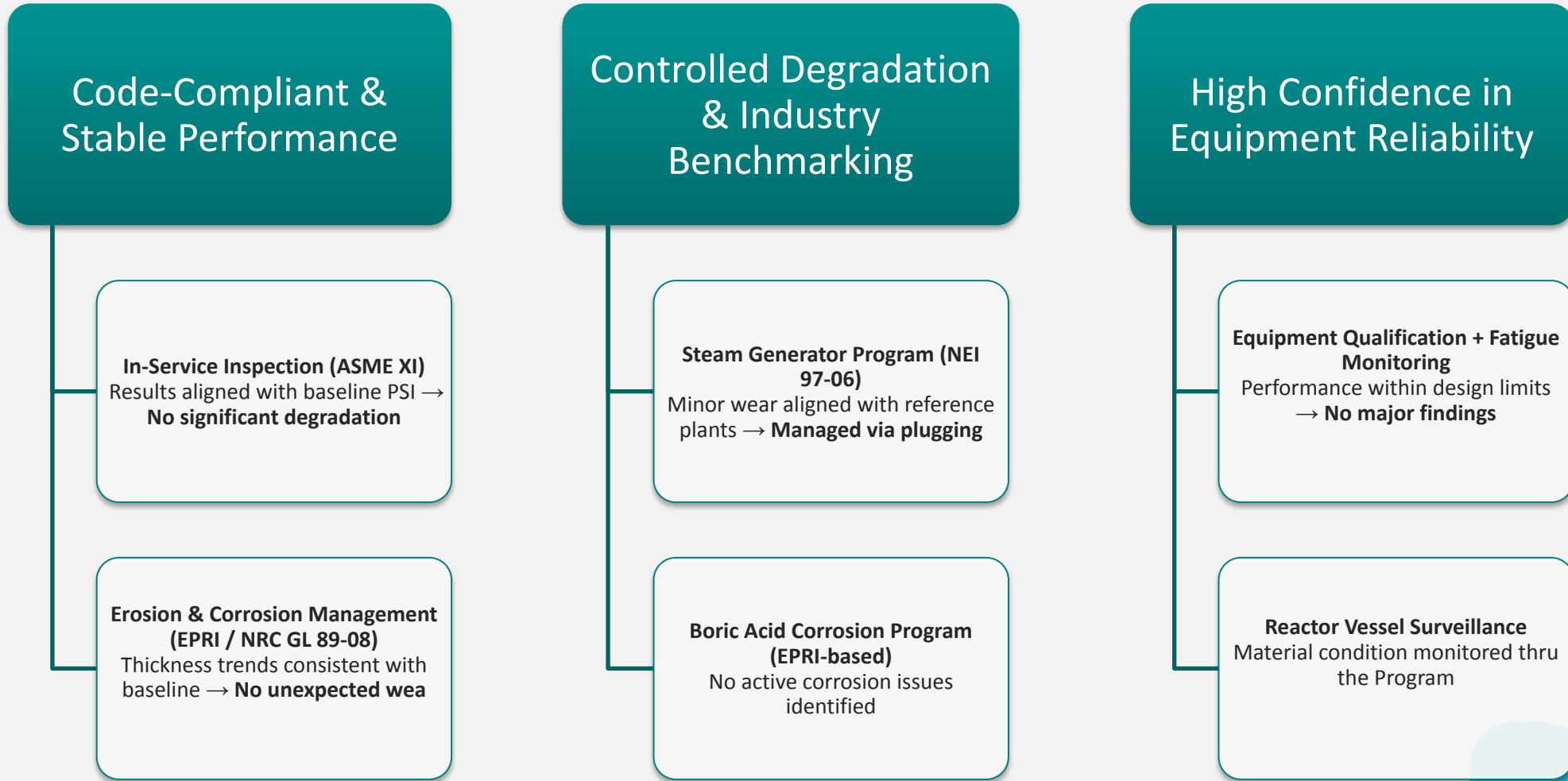
Early detection,
accurate trending,
and lifecycle
confidence





Aging Management throughout the NPP lifetime

Applying Lesson Learnt & Ageing Management during Operation:



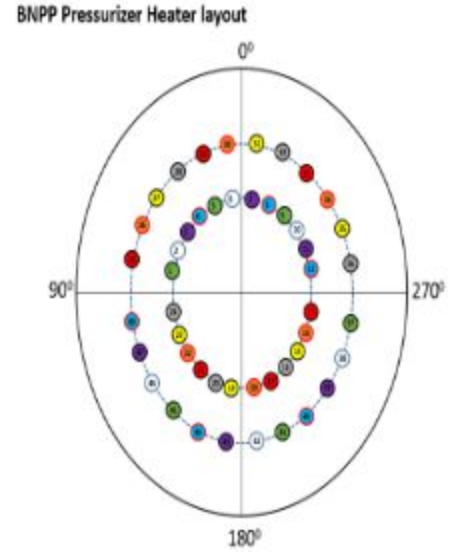
Baseline integrity is being preserved – Ageing effects are predictable, monitored, and controlled



Aging OE- Pressurizer Heater



Heater P2-31



Heater Seath Failures

Seath is made of SS 316 grade. BNPP has seen few failures in past on the heater Seath cracking - IGSCC.

Heater Sleeve Failures

PZR Heater Sleeve - Inconel 690 TT material.

OE- 02 Sleeve failures

Creep damage - Localized heat source inside the cold section of the heater due to element melting in the hot section.



Heater P1-37

PREVENTION
<ul style="list-style-type: none"> Faulted heater isolated to prevent any further fault progression that could result in RCS leakage. Replacement of heaters with improved design when failed to prevent reoccurrence. Project ongoing to develop new heater design that eliminates RCS leakage risks.

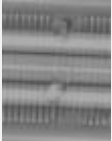
DETECTION
<ul style="list-style-type: none"> Effective implementation of the Adverse Condition Monitoring Plan (ACMP) to detect ground faults and current changes. Thorough investigation and troubleshooting to identify faulted heater. Sharing of lessons learned with other Ops crews to help recognition.

CORRECTION
<ul style="list-style-type: none"> Operational Decision Making Process used for structured assessment of risk and forward actions. Faulted heater identified and isolated to stop fault progression and restore margin to the Operators.

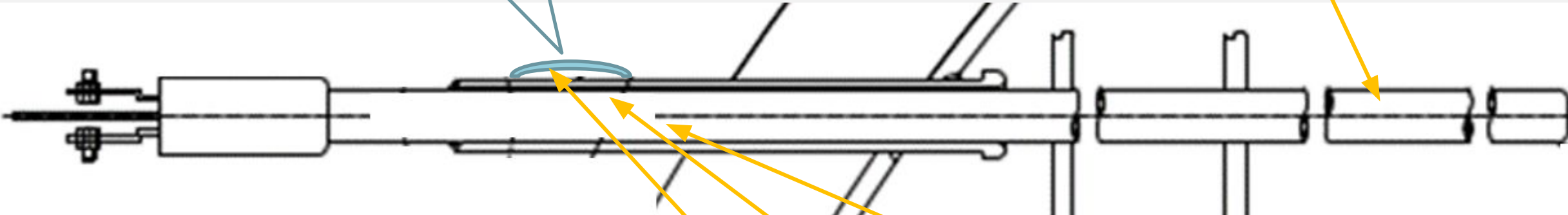


Aging OE- Pressurizer Heater contd.

Leakage position



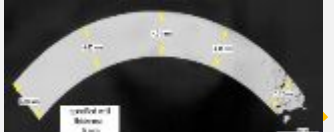
1st Stage :Some of 3 sets of heater elements failed



2nd Stage :As a result of the element failures, 2 of 6 Ni conduit wires carried the full current and overheated



3rd Stage : 316L Stainless steel Sheath overheated 715°C <Temp >870°C; Time>2000h Mostly σ -phase precipitated



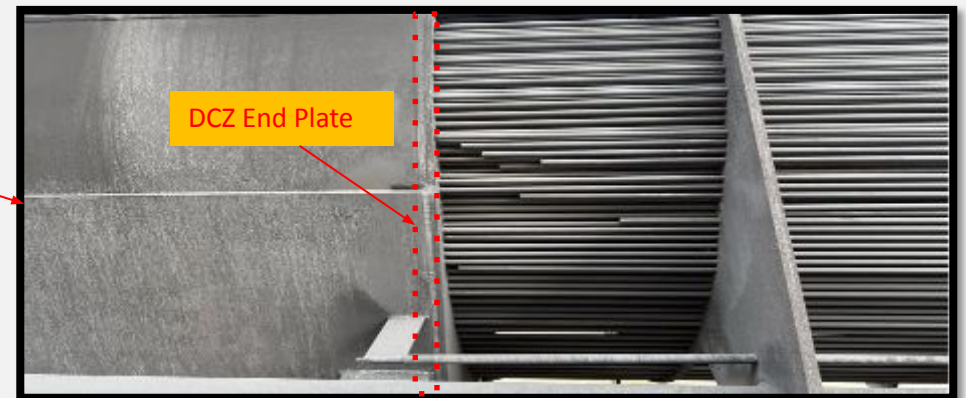
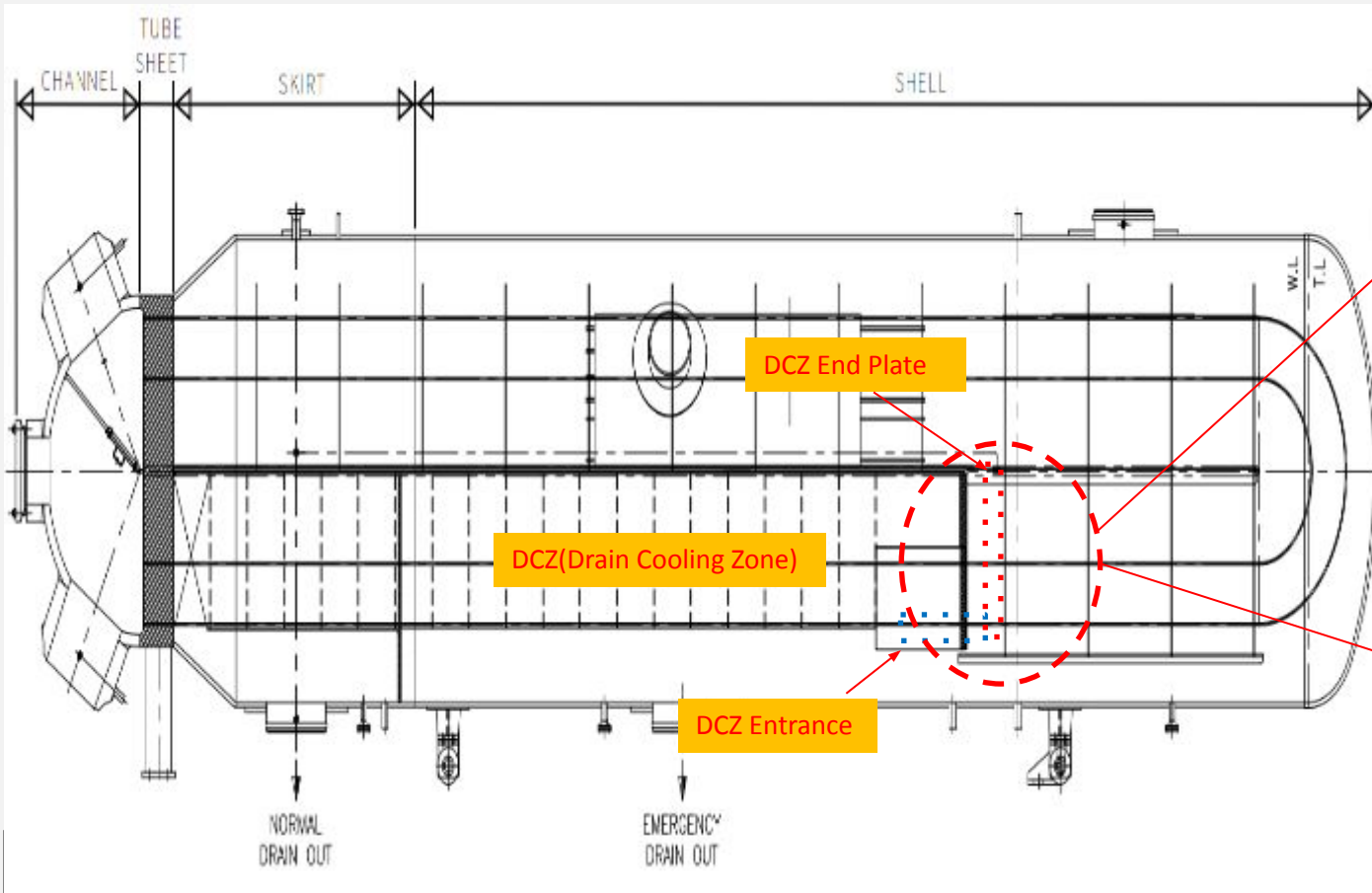
4th Stage : Inconel 690 Sleeve exposed to Creep temperature range and time whilst operating @155Bar – Temp >700 °C - 850°C; Creep Time<2900h
FINAL FAILURE CAUSING THE LEAK
THIS MECHANISM HAS NOT BEEN RECORDED IN INDUSTRY





Aging OE- Feed Water Heater 05B Failure

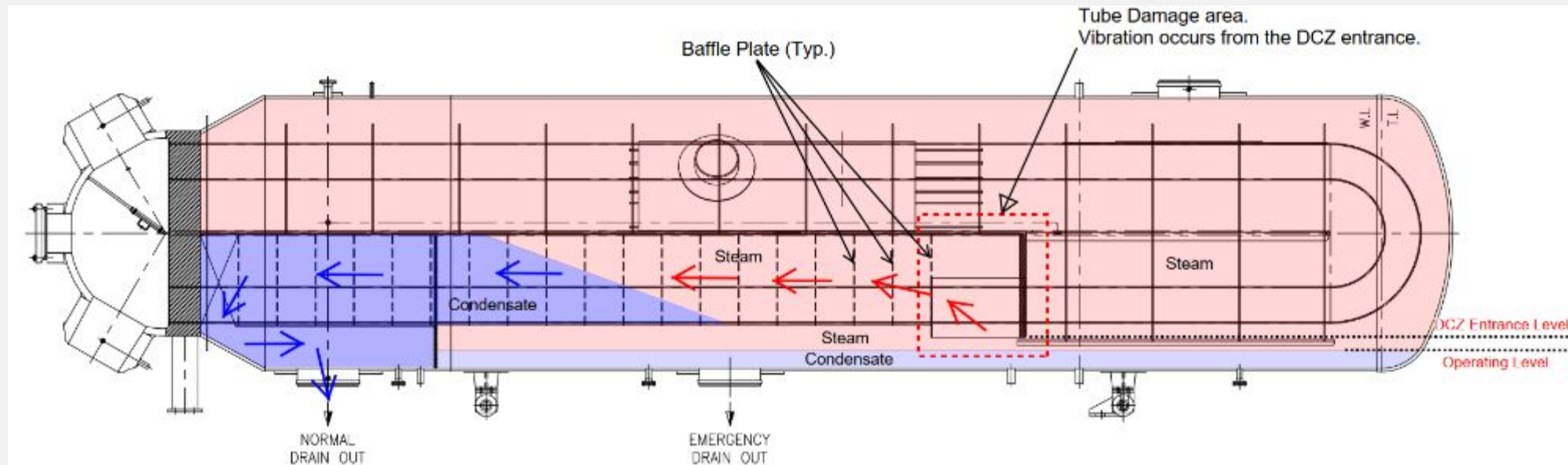
All sheared tubes were found around the end plate of the DCZ, and based on the appearance of the fracture surfaces, the failure appears to be fatigue failure caused by vibration near the DCZ entrance. It was confirmed that the hole of the upper pressure measurement nozzle on the shell, which is used for level measurement, was blocked inside the shell by a plate





Aging OE- Feed Water Heater 05B Failure contd.

It is presumed that the HTR was operated for an extended period with the water level lower than the DCZ entrance, allowing a large amount of steam to flow into the Drain Cooling Zone (DCZ). Since steam is in a gaseous state and has a larger volume than condensate, the inflow of a large amount of steam increases the steam flow velocity in the DCZ. This increased velocity induces tube vibration, and the continuous vibration is believed to have caused damage to the tubes around the DCZ end plate.





Aging OE- Socket Weld Failures

Location

¾" socket weld, **Shutdown Cooling Drain Line**, near HEX throttling valve

Failure Mode

- **High-cycle fatigue (HCF)** induced by pipe vibration
- Vibration source: **Valve throttling of SCS heat exchanger control valve**
- Crack initiated at **outside diameter (OD)**

Failure Evidence

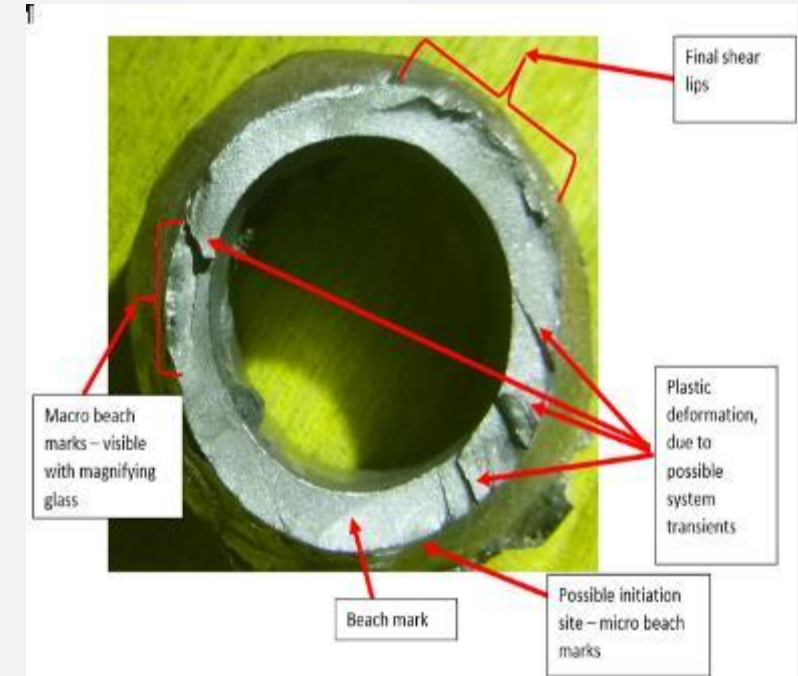
- Presence of **fatigue striations / beach marks** on fracture surface
- Crack propagation consistent with **cyclic loading mechanism**

Root Cause

- **Flow-induced vibration** due to excessive valve throttling
- Susceptibility of **socket weld geometry** to stress concentration under dynamic loading

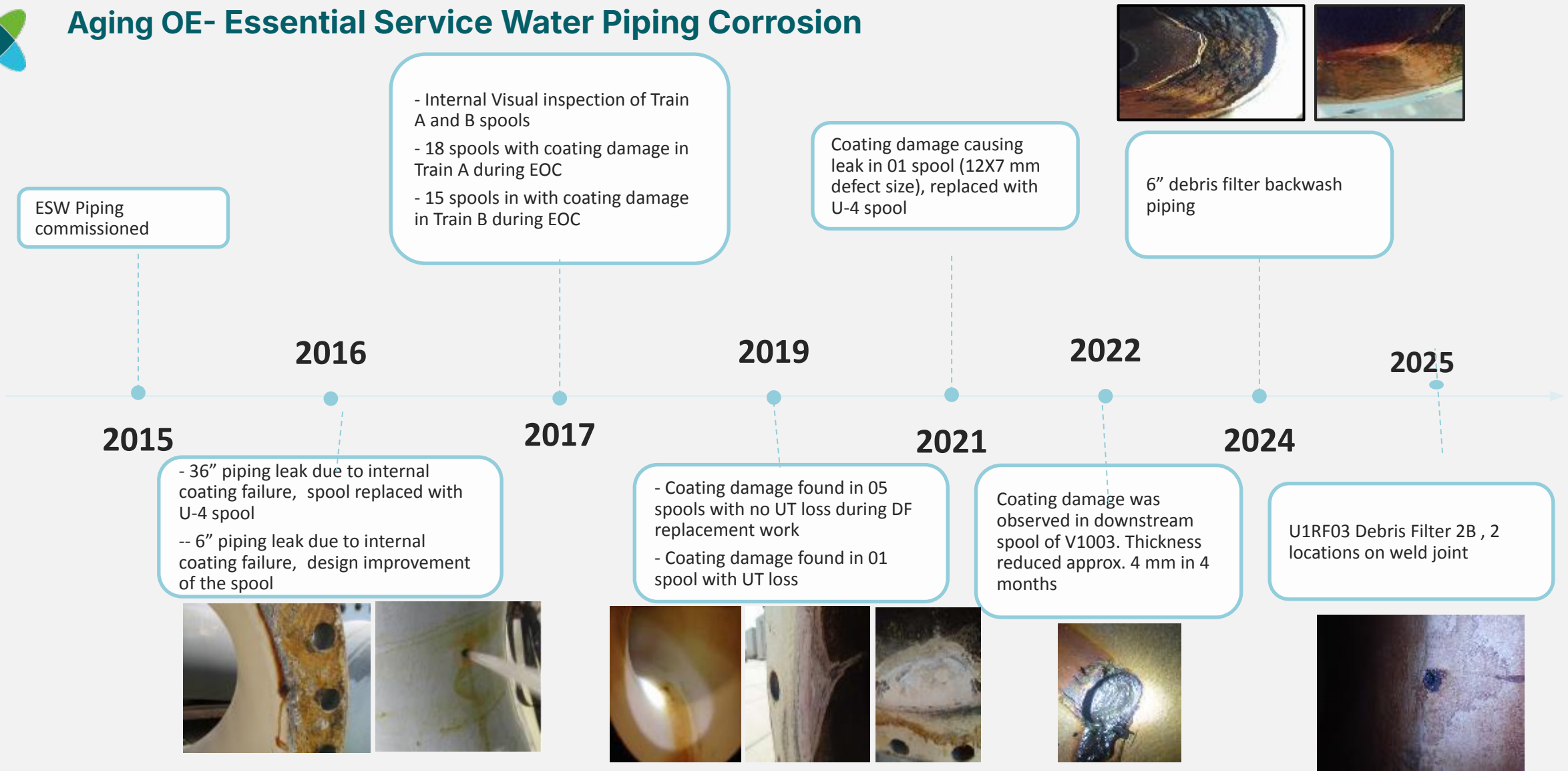
Corrective Actions

- **Operational control:** Limit/control valve throttling range
- **Design improvement:** Socket weld enhancement in line with EPRI guidance





Aging OE- Essential Service Water Piping Corrosion



ESW Failures



Aging OE- Essential Service Water Piping Corrosion contd.

Equipment Strategy

Regular Monitoring and Inspection – UT/VT

Monitoring

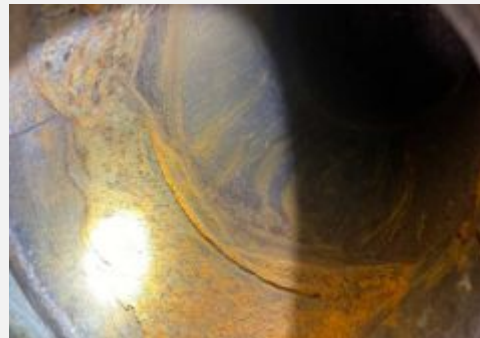
Check for Biocide Injection

Regular Maintenance

Code complaint repairs if Safety Class

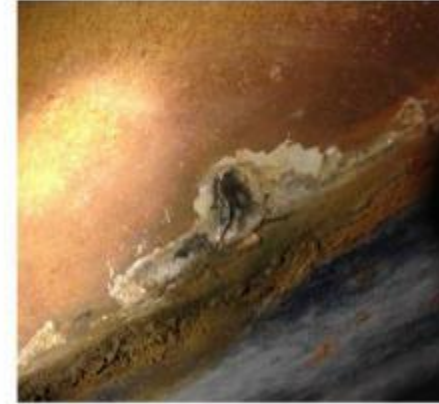


Unit -2 Yr. 2024

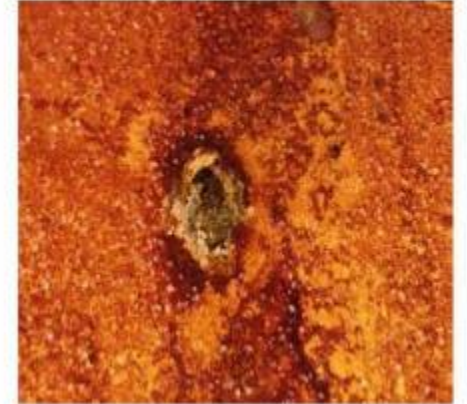


Unit -3 DF Back wash piping

Damaged Lining Parts inside Spools



Spool No. : 2-462-P-SX004-811



Spool No. : 2-462-P-SX004-811



Spool No. : 2-462-P-SX004-815



Spool No. : 2-462-P-SX004-818



Aging OE- Stainless Steel Liner Plate

Location

- Spent Fuel Pool and IRWST Liner plates made of **Stainless-Steel SS 304**
- Most of the defects found on **weld seam and Heat Affected Zone (HAZ)**, not on base material.

Failure Mode

- Cracking at the main seam welding of Liner plates
- Identified during the construction phase

Failure Evidence

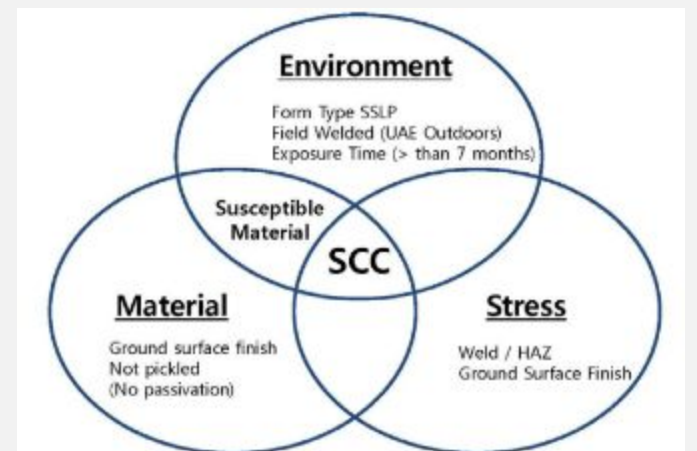
- Cracking at main seam welding identified during penetrant testing.
- Replica test results showed cracks with branching characteristic of **stress corrosion cracking (SCC)**

Root Cause

- Chloride induced Stress Corrosion Cracking (**CL SCC**)
- Prolonged exposure to aggressive marine environment and inadequate cleanliness requirements.
- Main Factors – Salte-laden atmosphere, Dust, high humidity etc.

Corrective Actions

- Repaired all the defects during the construction and verified with required testing.
- The liner plates are installed in controlled environment.





Q&A / Discussion

