ELMO - Extended lifetime of structural materials through improved water chemistry

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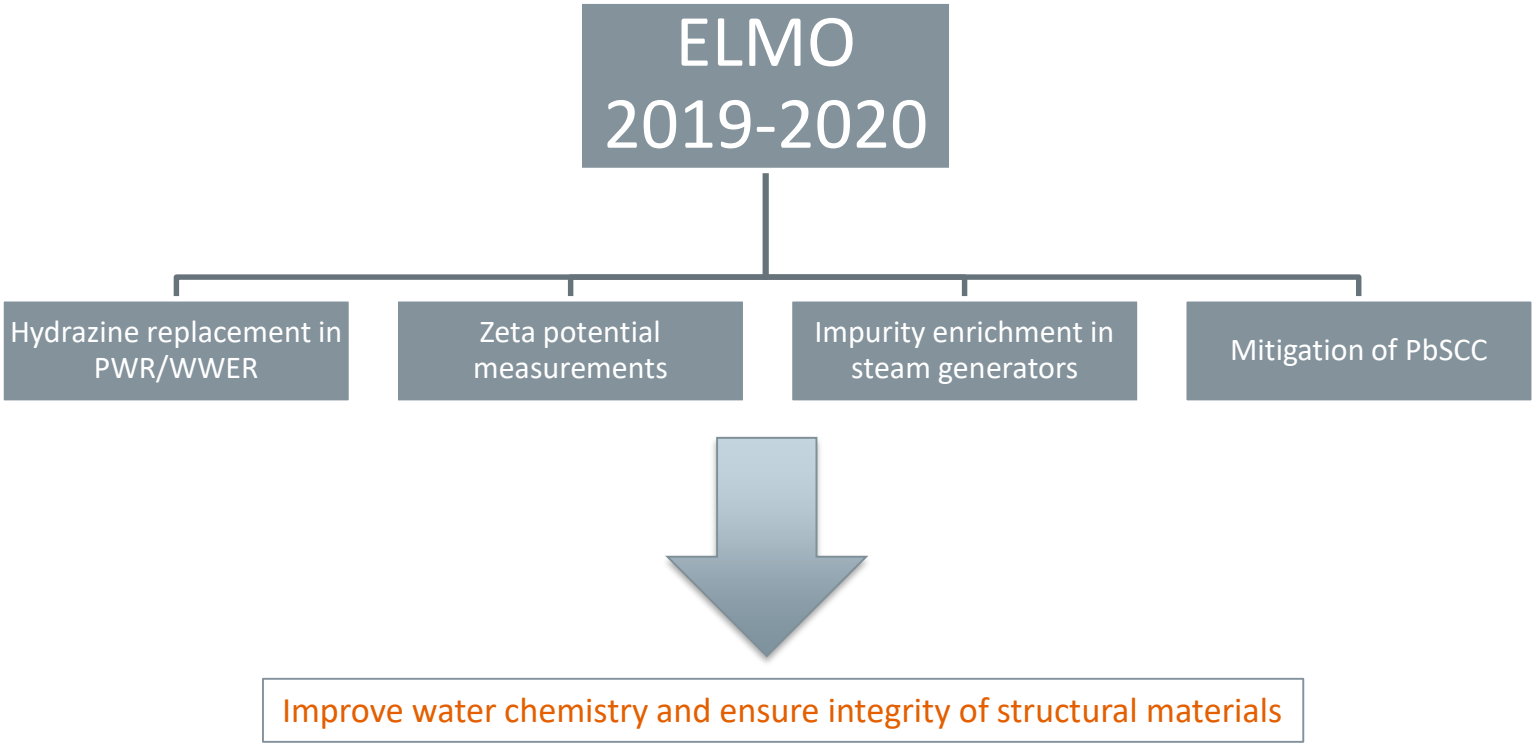
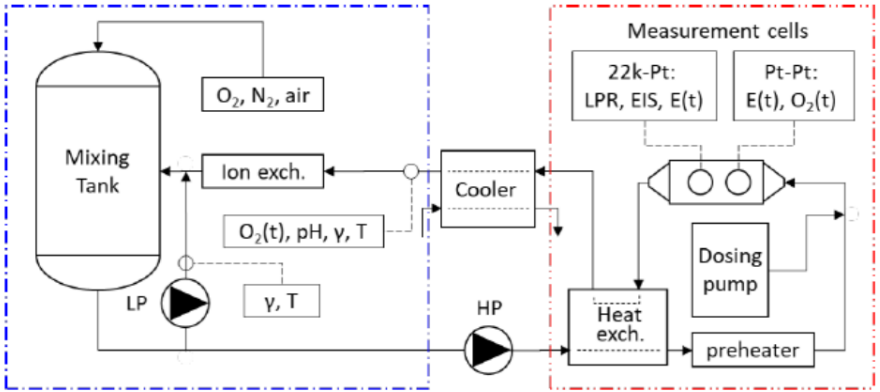

ELMO
2019-2020
Hydrazine replacement in PWR/WWER
Zeta potential measurements
Impurity enrichment in steam generators
Mitigation of PbSCC
Improve water chemistry and ensure integrity of structural materials

Hydrazine replacement in PWR/WWER

- Hydrazine used as oxygen scavenging chemical
- Goal: find suitable substitute for hydrazine
  - 2019-2020 Define the oxygen scavenging efficiency of potential substituting chemicals at secondary side feed water temperature T=228°C

Experimental setup



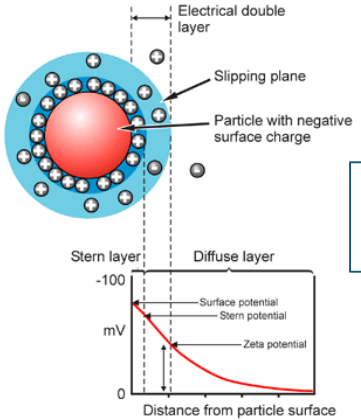
Experimental results

Oxygen scavenger	Kinetic equation	Initial rate at scavenger concentration 25 µmol dm^{-3} / µmol dm^{-3} s^{-1}
Hydrazine	$r = kc_{O_2}^{1} c_{N_2H_4}^{1}$	0.103
Erythorbic acid	$r = kc_{O_2}^{1} c_{EA}^{1}$	0.093
Carbohydrazide	$r = kc_{O_2}^{1} c_{CH}^{0.6}$	0.171
Diethyl-hydroxylamine	$r = kc_{O_2}^{1} c_{DEHA}^{1}$	0.031
Methyl-ethyl-ketoxime	$r = kc_{O_2}^{1} c_{MEKO}^{0.5}$	0.015 (E-t) 0.008 (O_2-t)

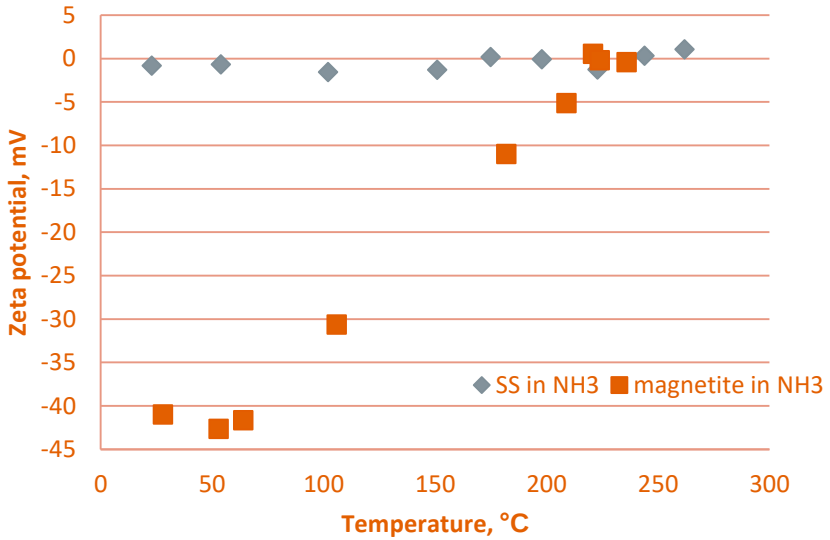
Essi Jäppinen, Tiina Ikäläinen, Frej Lindfors, Timo Saario, Konsta Sipilä, Iva Betova, Martin Bojinov. A comparative study of hydrazine alternatives in simulated steam generator conditions — Oxygen reaction kinetics and interaction with carbon steel. Electrochimica Acta 369 (2021) 137697. https://doi.org/10.1016/j.electacta.2020.137697

Zeta potential measurements in simulated steam generator environment

- Magnetite deposits in steam generators
- Goal: clarify the role zeta potential in formation of magnetite depositions in steam generators
- 2019: ZP measurement of SS in secondary side water
  - SS has near zero ZP value over the measurement range
  - → No strong attractive force between magnetite and SS
- 2020: Data quality verification



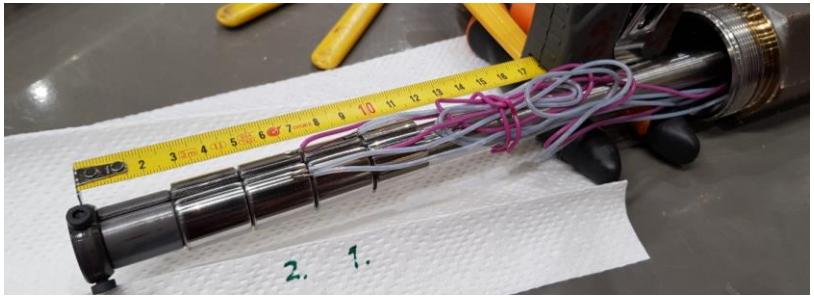
$$\zeta = \frac{U_{str}}{\Delta P}\frac{4\eta l}{\epsilon_{rs}\epsilon_o r^2 R}$$

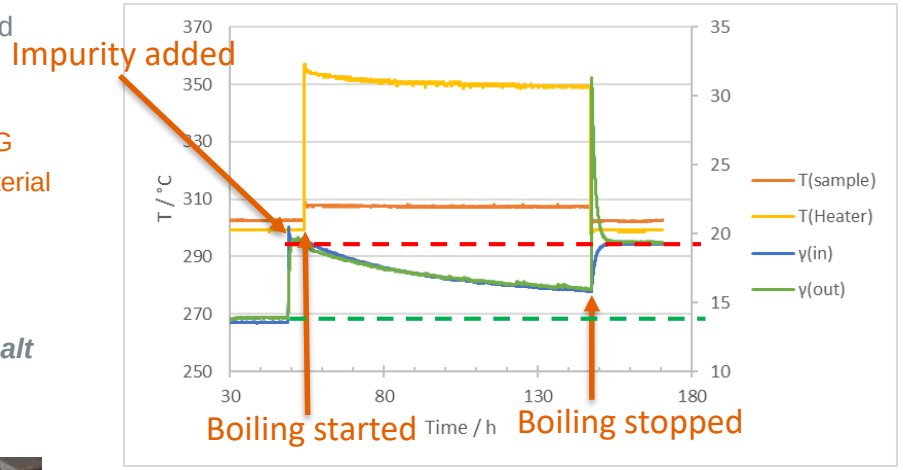


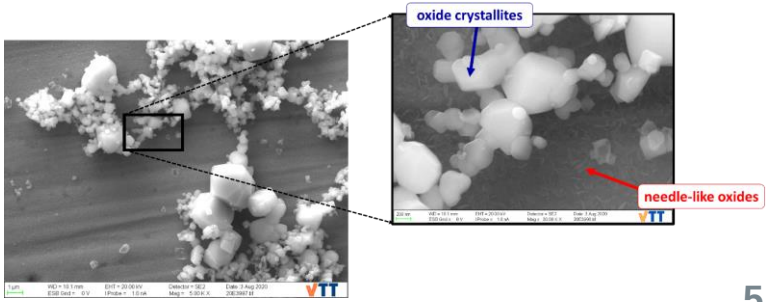
Zeta potential of stainless steel and magnetite in secondary side water treated with ammonia as function of temperature

Impurity enrichment in steam generators

- Impurities, such as sulphates and chlorides, can be enriched on boiling surfaces
- Goals:
  1. Define deposition and release kinetics of impurities in SG
  2. Define the effect of boiling to corrosion of SG tubing material
- Equipment that simulates a steam generator tube
- Conductivity and ICP-MS measurements
  → Calculate deposited amounts are release rates
  Deposition occurs when impurities are added as a salt
- In-situ EIS measurements
- Ex-situ microstructure characterization

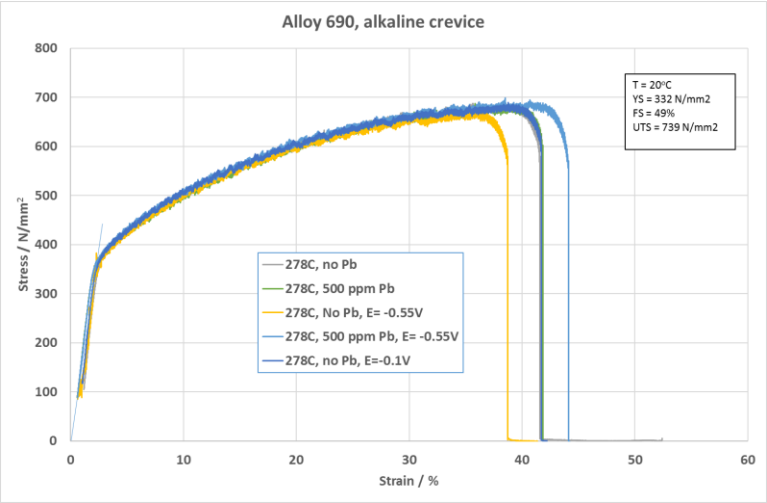


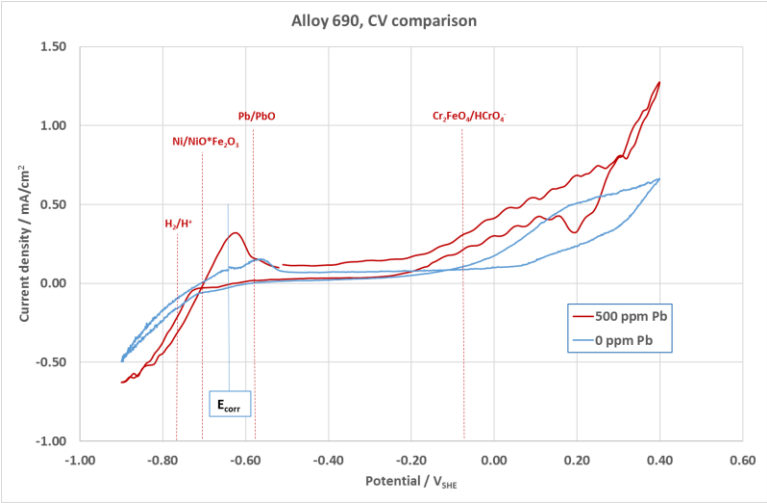




Mitigation of PbSCC

- Alkaline crevice conditions are likely to be present in operating SGs [1]
- Goal: Define PbSSC susceptibility of A690 in alkaline crevice conditions with 500 mg/l Pb at T = 60°C and T = 278°C
- SSRT, SEM, CV, EIS and GDOES analyses indicate that A690 is not susceptible to PbSCC in the studied environments





[1] K. Matocha, G. Rožnovská, V. Hanus, The effect of lead on resistance of low alloy steel to SCC in high temperature water environments, in: D. Féron, J.-M. Olive (Eds.), Corrosion issues in light water reactors. Stress corrosion cracking, European Federation of Corrosion Publications 51, Woodhead Publishing, 2007, pp. 70-75.

ELMO 2019-2020 summary

- Various nuclear power plant water chemistry related topics have been studied within ELMO project:
  - The efficiency of alternative oxygen scavenging chemicals at operating temperature
  - Zeta potential measurements of stainless steel in PWR secondary side chemistry as function of temperature and data quality verification
  - The boiling conditions in a steam generator can be simulated
  - A690 seems not be susceptible to PbSCC in a representative alkaline crevice conditions

Thank you!