SAFIR 2018 / MOCCA
Mitigation of cracking through advanced water chemistry

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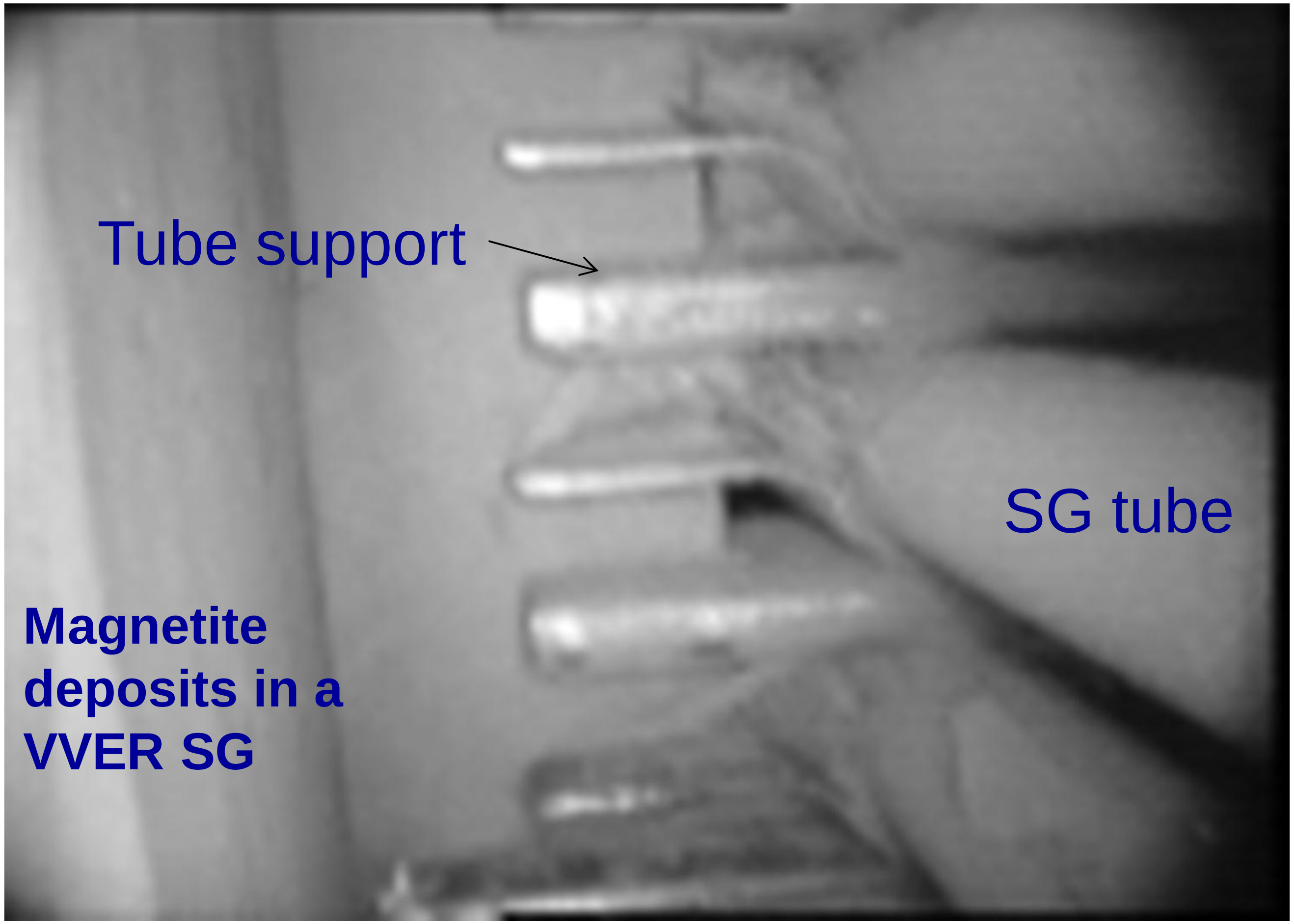
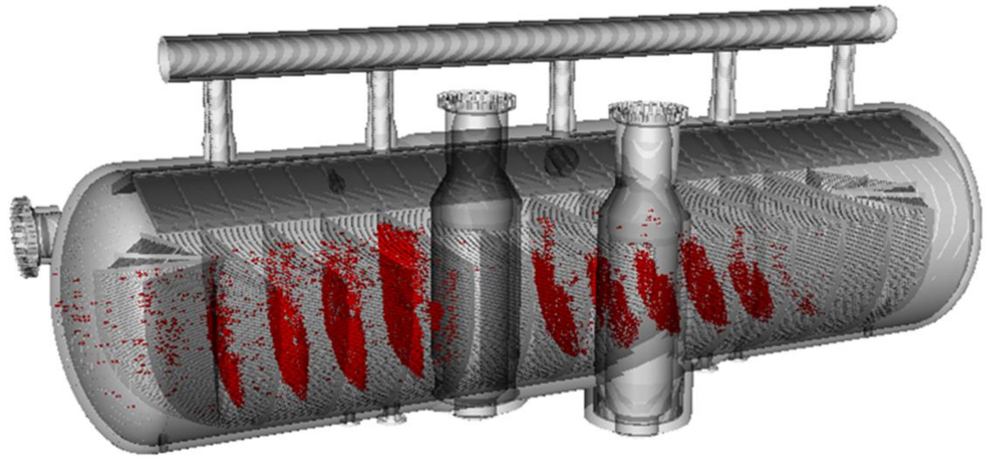
Background



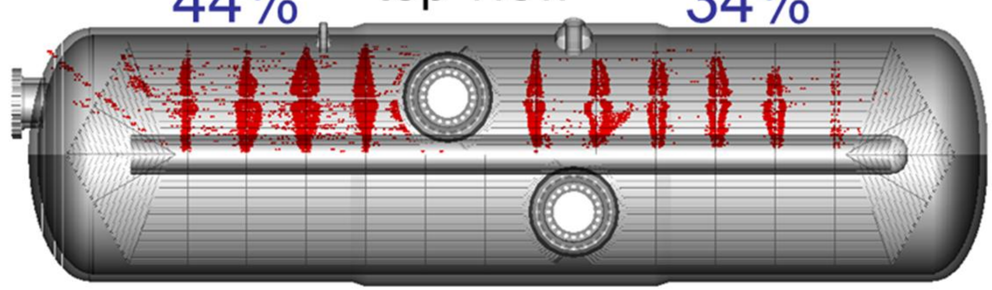
Magnetite (Fe_3O_4) oxide particles are formed from corrosion of feed water line materials. When carried by flow to SG and deposited there they may cause corrosion of SG tubing and primary to secondary side leakage.

Background

Magnetite deposits
in Loviisa steam generator
hot leg



Feed water distribution



Background

Magnetite deposition can be mitigated by several means:

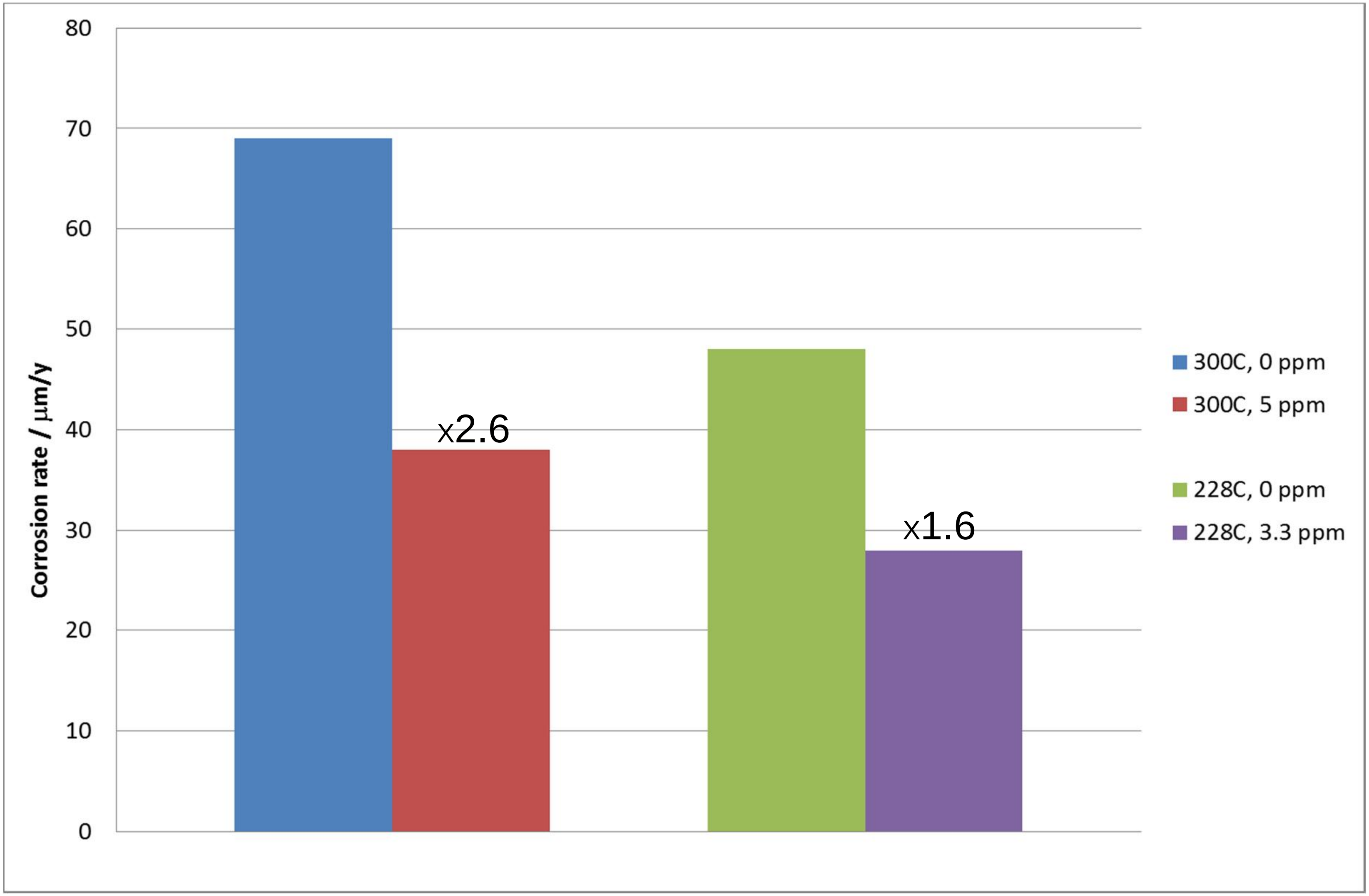
1) **Improving the passivation of feed water line materials;**
   a) increasing pH to 9.6 < pH < 9.8,
   b) *using a film forming amine, e.g. octadecylamine (ODA)*
   c) *using hydrazine (N_2H_4)*

2) **Keeping the magnetite particles in colloidal form so that they can be filtered out (blow down, HT filters);**
   a) *choosing a mixture of amines to change the surface charge of magnetite*,
   b) adding dispersion agents, e.g. poly acrylic acid (PAA)

3) **Removing existing deposits mechanically or chemically**

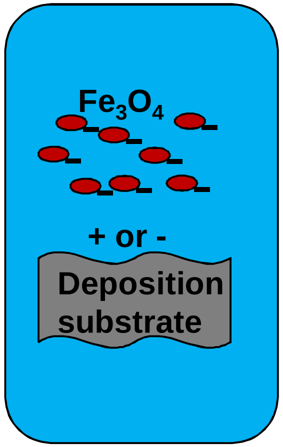
Note: Items in red are studied within the MOCCA-project

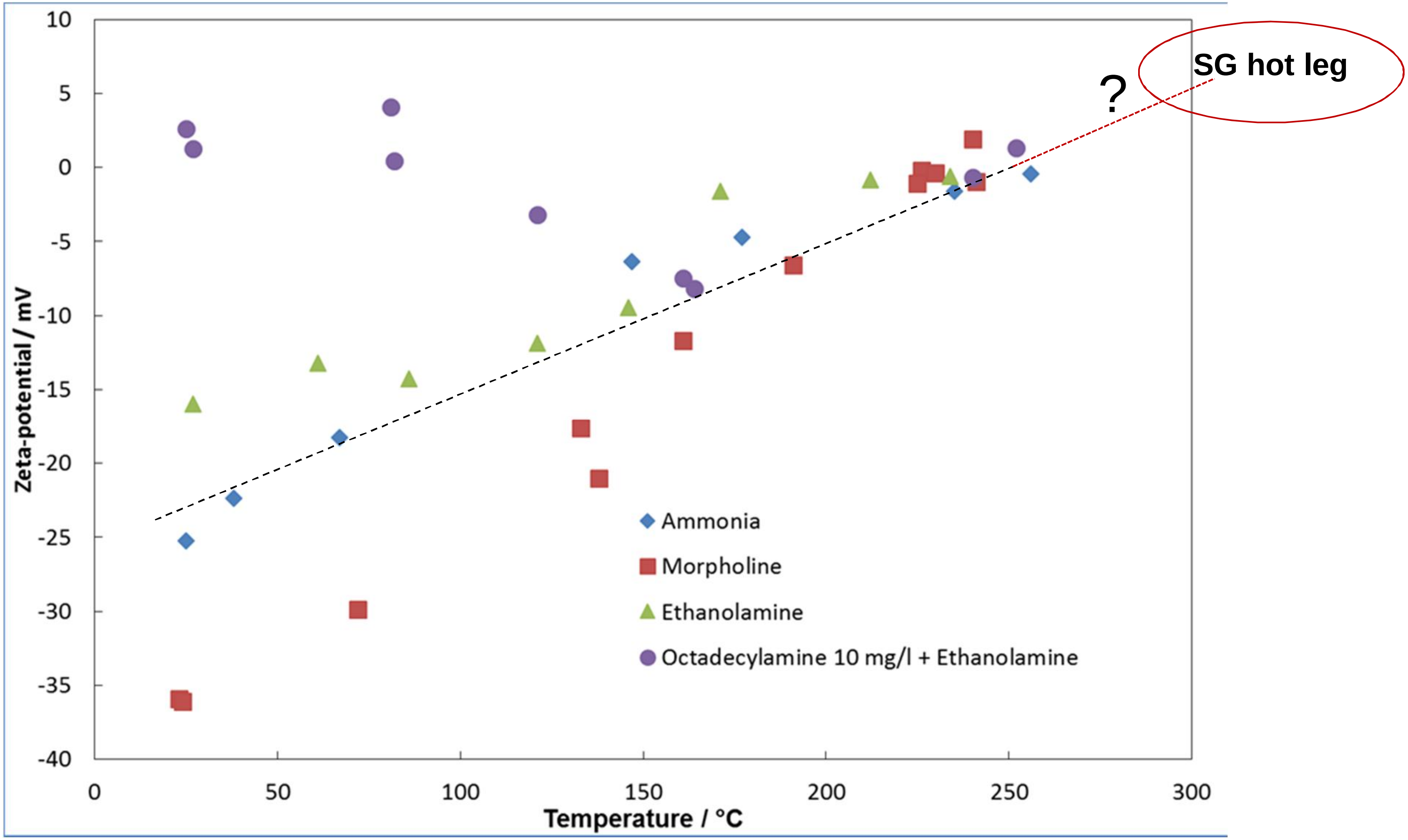
Octadecylamine, ODA



Effect of ODA on carbon steel corrosion resistance in PWR secondary side water, pH = 9.8, corrosion rate measured with weight loss coupons

Effect of different amines and temperature on magnetite surface charge = zeta potential





Will the trend continue when T → 300°C?

Background: Mitigation of PbSCC

If you get magnetite deposition into SG → risk of lead assisted stress corrosion cracking (PbSCC) of SG tubing and SG body

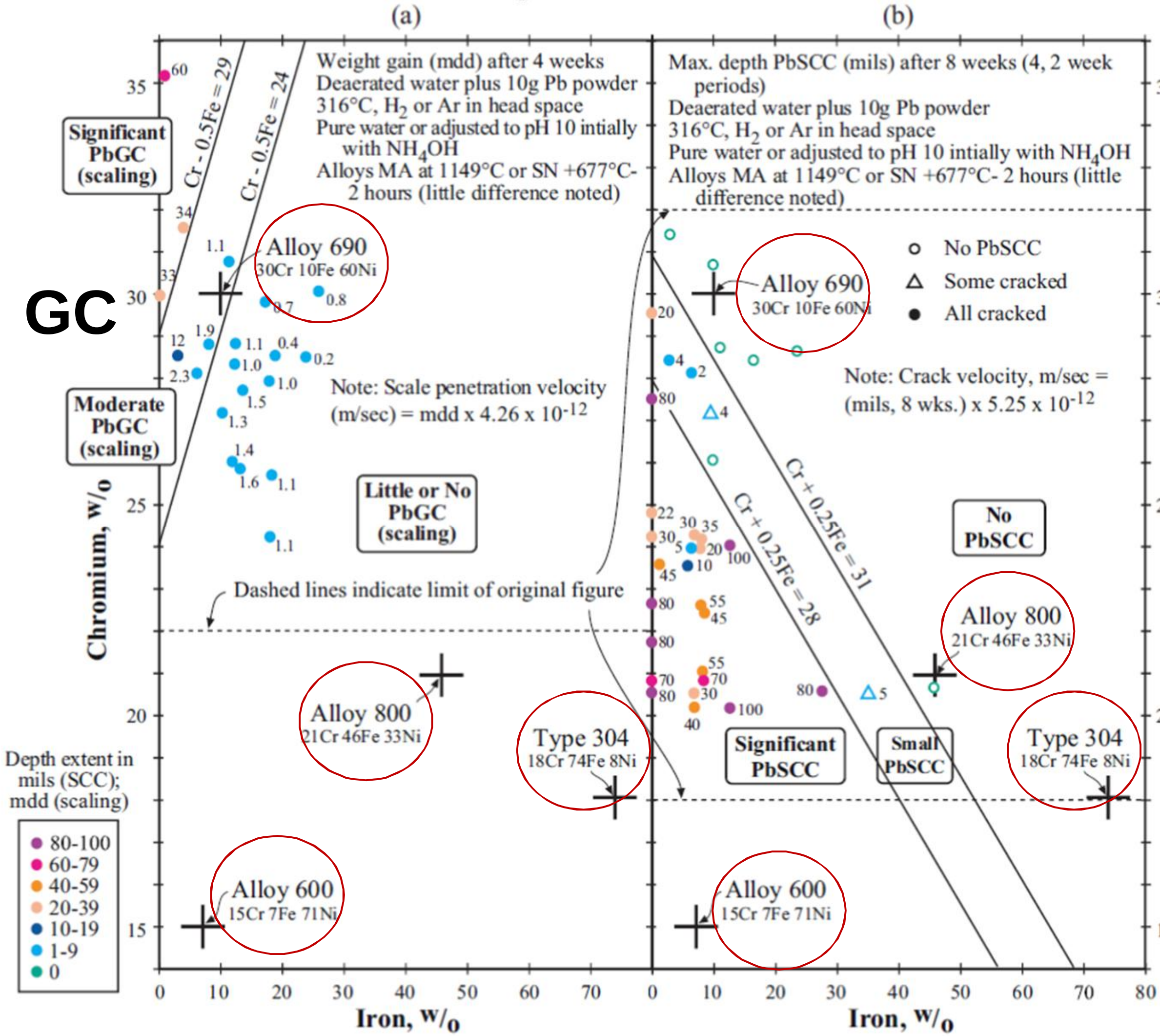
Lead in the PWR / WWER secondary side

- The typical feed water Pb concentration is 4-20 ppt (10^{-12} kg/kg), and that at SG blowdown 120-330 ppt during normal operation. There is no specific limit for Pb in light water reactor secondary systems.
- For a typical PWR the total feed water Pb transport rate is about 550 grams/year, most of which is accumulating in the steam generator.
- **In most plants, Pb has been found at concentrations of 100-1000 ppm (10^{-6} kg/kg), in crevices, sludge piles and under deposits in free span regions of SG where impurities typically concentrate**.

Background: Mitigation of PbSCC

Lead assisted general corrosion and SCC

GC



SCC

Cr vs. Fe diagrams for PbGC (a) and PbSCC (b)
after testing in pure water with 10 g of Pb added at 316 °C.

Carbon steel = SG body

very limited studies show susceptibility to PbSCC

Target for MOCCA – project

MOCCA project: Mitigation of PbSCC

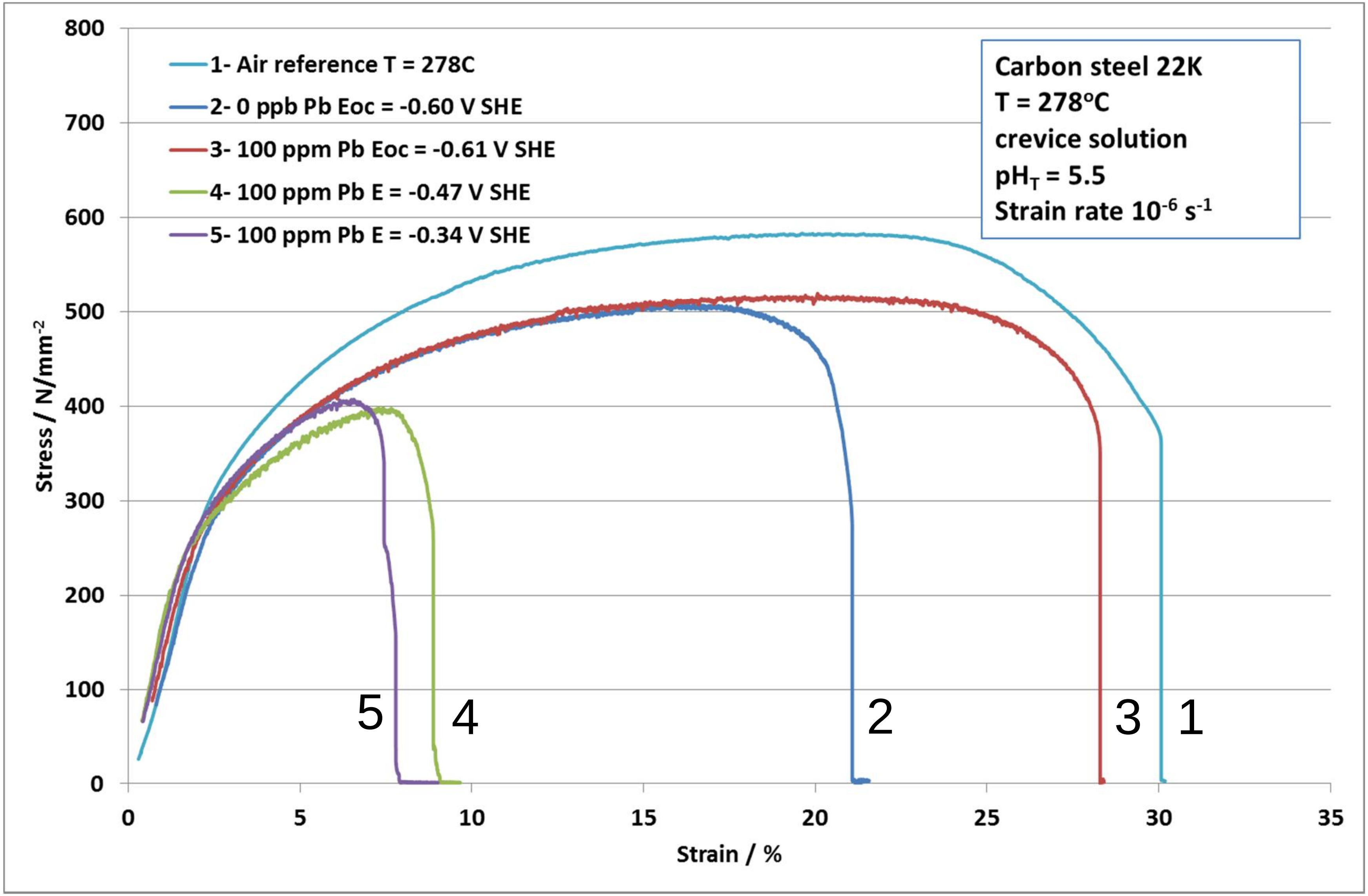
- An experimental arrangement for studying SCC in simulated SG environment has been developed

- The experimental arrangement has been verified by a limited experimental program on susceptibility of carbon steel 22K (VVER SG primary collector body material) to PbSCC

- The test environment was a crevice solution at T = 278^{o}C (modeled with MULTEQ-software) representative of VVER SG and earlier used by a Czech research group, i.e. 330 ppm NaCl, 740 ppm Na_2SO_4 and 102 ppm H_2SO_4, pH_{278} = 5.5.

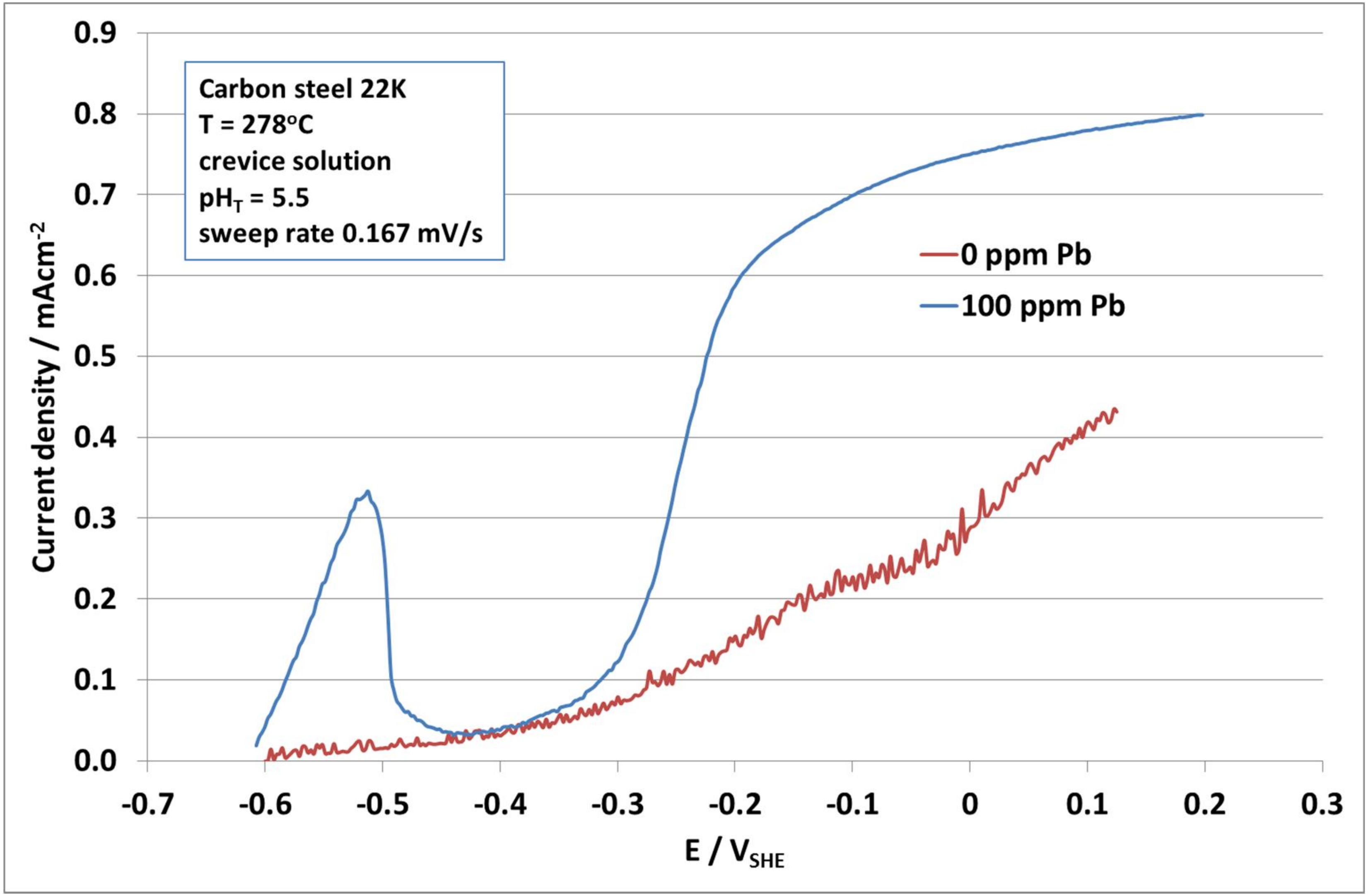
Mitigation of PbSCC

Mechanical testing in the crevice environment forming under the magnetite deposit



Mitigation of PbSCC

Electrochemical measurements: polarisation curves



Mitigation of PbSCC

Concentration of Pb on the surface after the tests

Test	$[Pb^+]$ / ppm	E / V_{SHE}	Pb/ w-% (EDS)
1	0	-0.600*	0.0
2	100	-0.610*	14.0
3	100	-0.42**	0.0
4	100	-0.35**	0.6

*corrosion potential, **controlled by potentiostat to more anodic (oxidative) potentials

- **At corrosion potential, Pb accumulates on the surface and prevents passivation, thereby mitigating SCC → high fracture strain (28%)**
- **At slightly anodic (oxidative conditions) Pb dissolves from the surface leaving behind a weak passive film very susceptible to SCC → low fracture strain (<10%)**

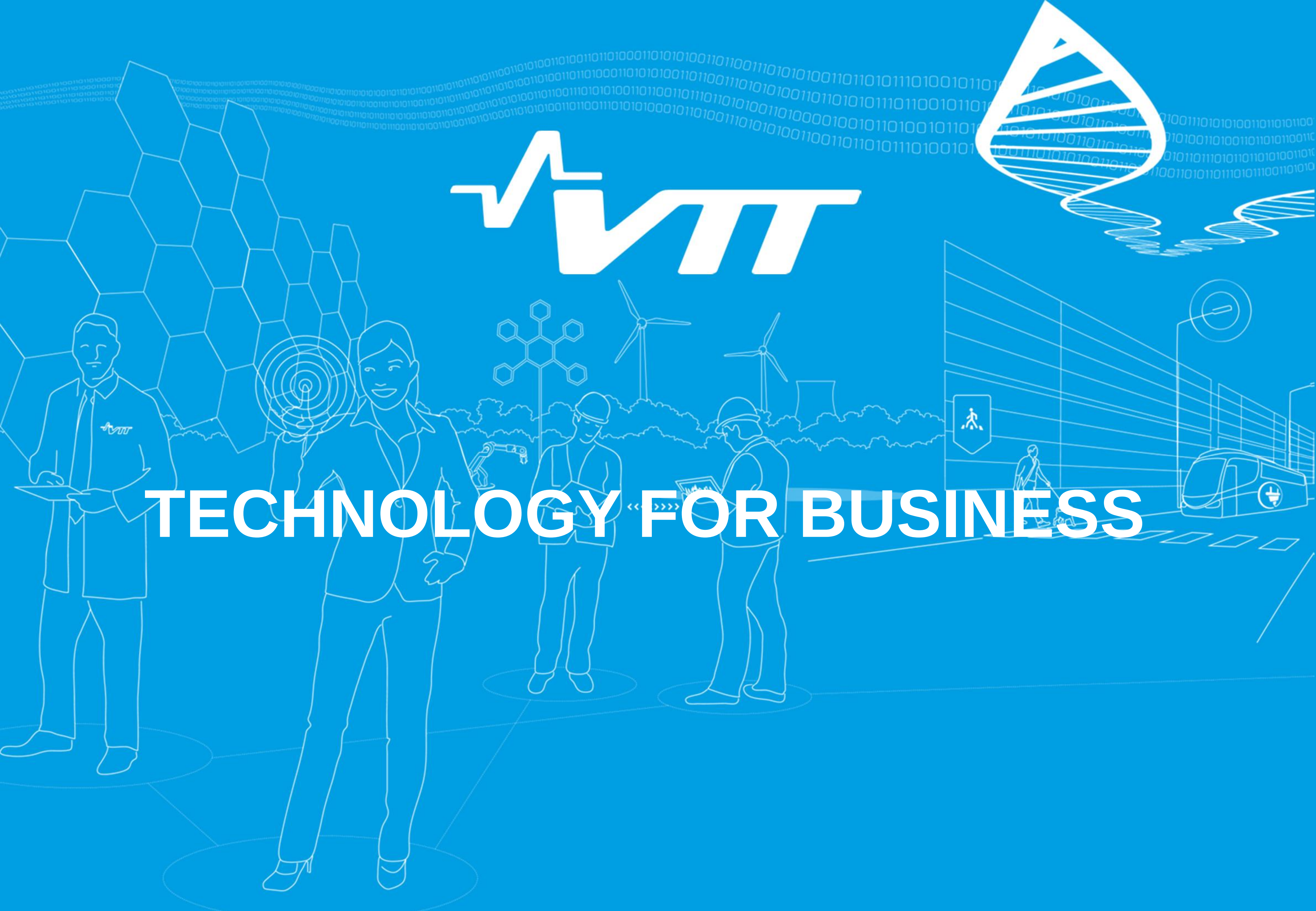
Conclusions

- **Controlling the deposition of magnetite particles into the SG is important in mitigating SCC of SG tubing and body.**

- **Film forming amines such as octadecylamine (ODA) can be used to improve feed water line passivation and thus reduce the amount of magnetite carried by the flow to the SG.**

- **At SG relevant temperatures, amines used to control pH (such as ethanolamine and morpholine) do not seem to have a substantial effect on magnetite surface charge and thus the tendency of magnetite to deposit into the SG.**

- **In an slightly acidic crevice environment, Pb was shown to mitigate SCC of carbon steel (SG body material). However, at elevated potentials simulating an oxygen inleakage, carbon steel was found to suffer from severe SCC.**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