NTNU

Norwegian University of Science and Technology

Solid silica precipitation, growth and deposition in depressurized supercritical steam

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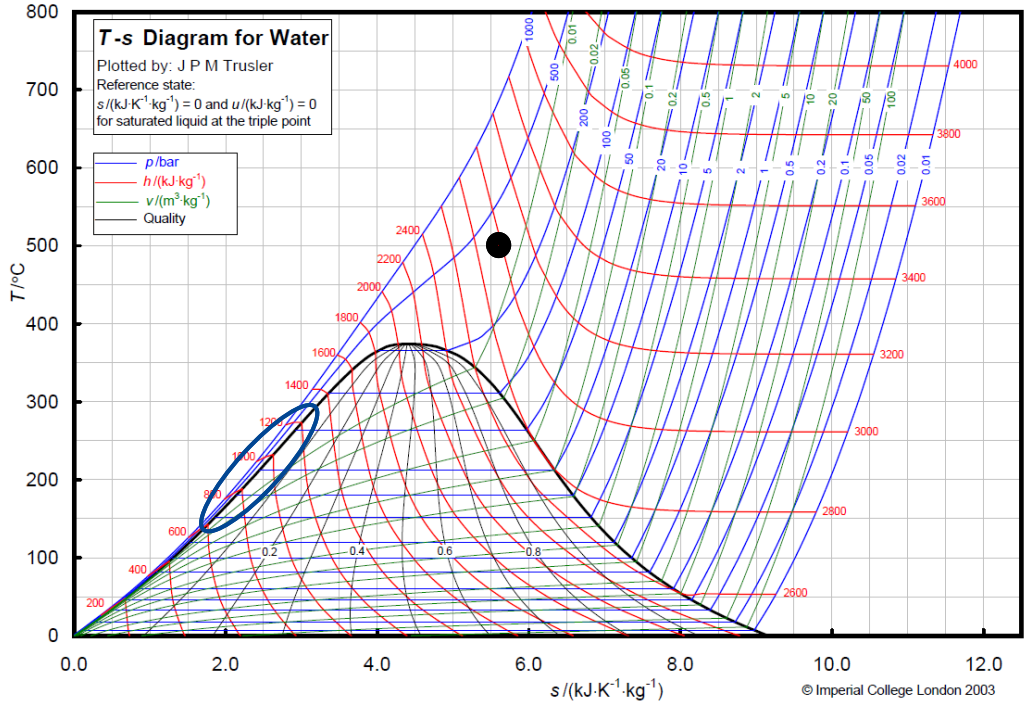
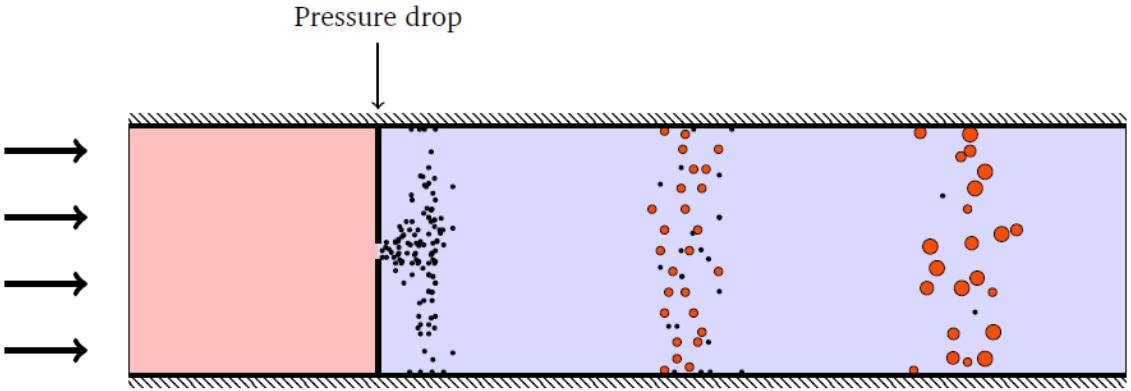
Project background

- Research project by NTNU in cooperation with IFE, Forskningsrådet, and Equinor through their investment in IDDP project and;
- Deep Geo
- Solubility

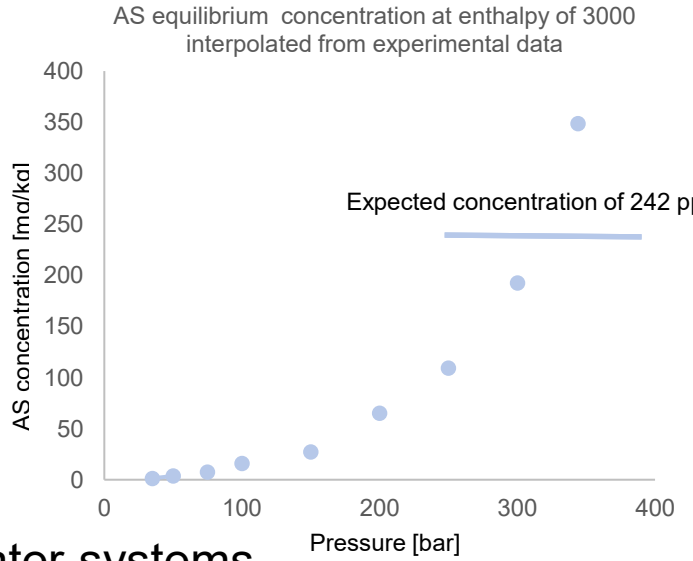


What happens upon depressurization?



Nucleation — Growth by agglomeration — Deposition

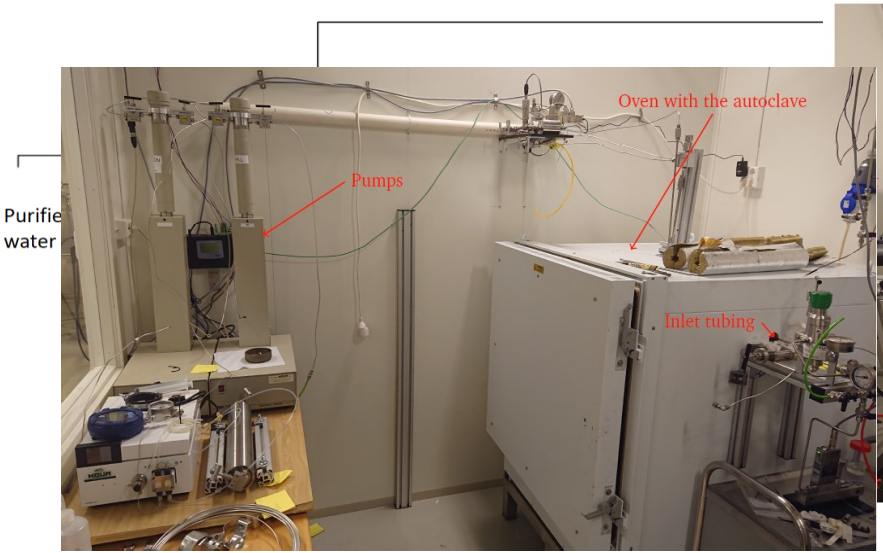
$$H_4SiO_4 \rightarrow SiO_{2(cn)} \rightarrow SiO_{2(nano)} \rightarrow SiO_{2(ppt)}$$

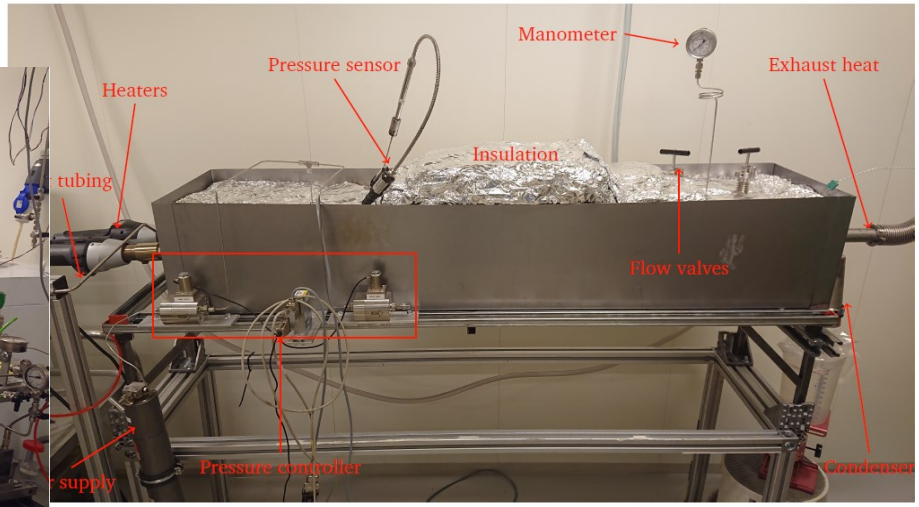


- How this case differ from silica precipitation in water systems

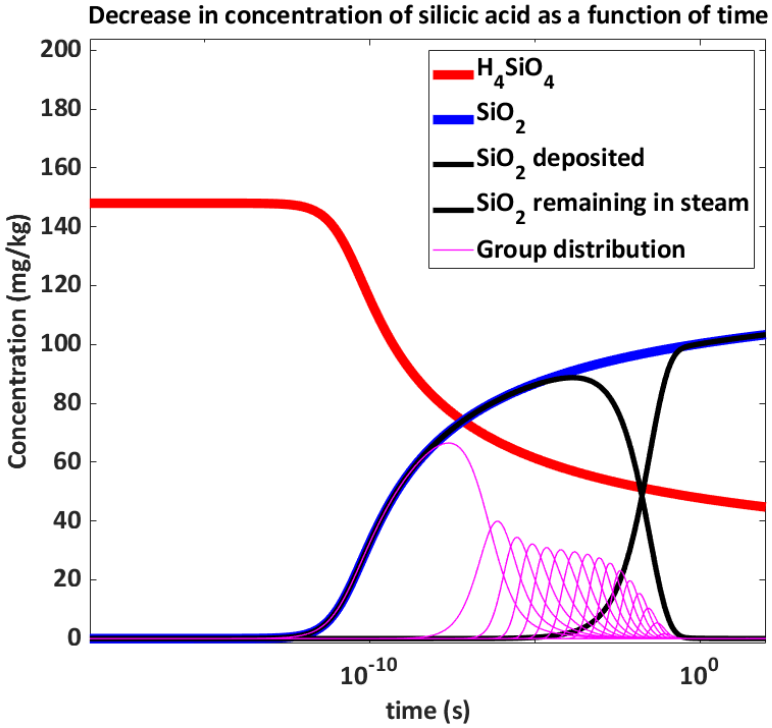
Experimental setup

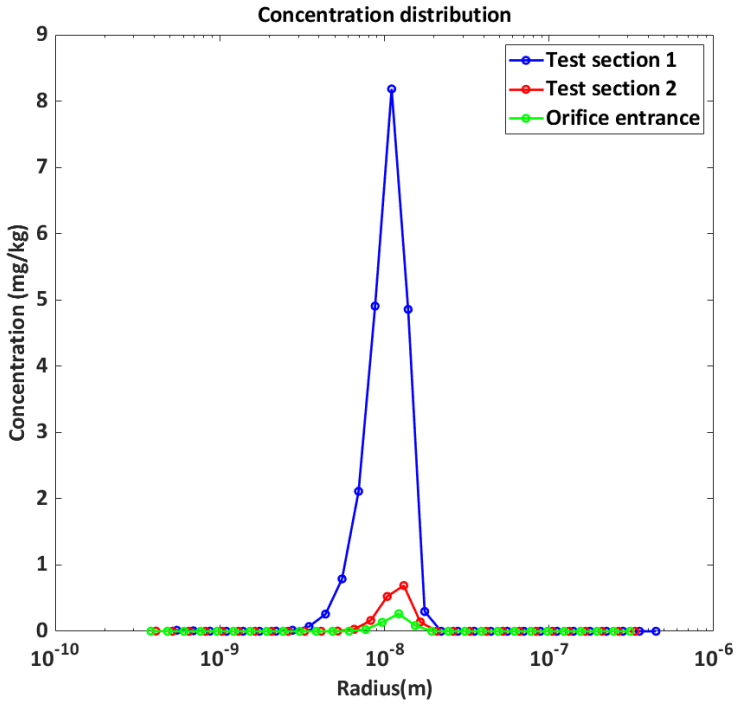
- Test rig built at NTNU- connected to a autoclave inside a heater at IFE (Morten Tjelta)



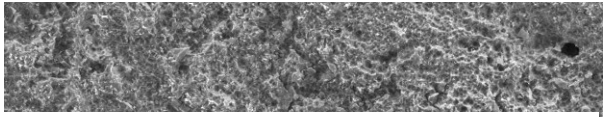


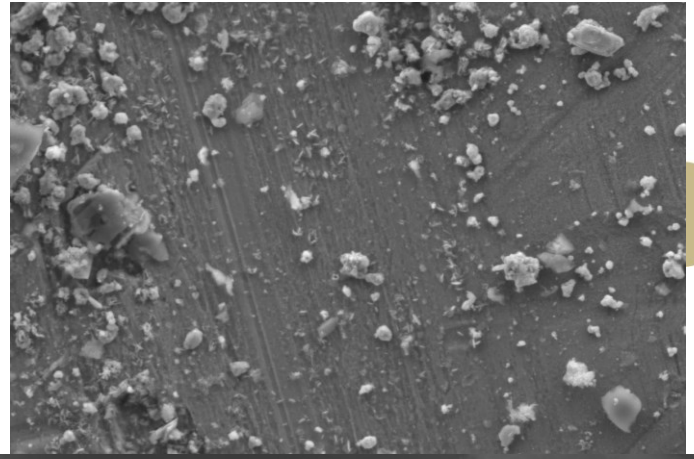
Modelled results

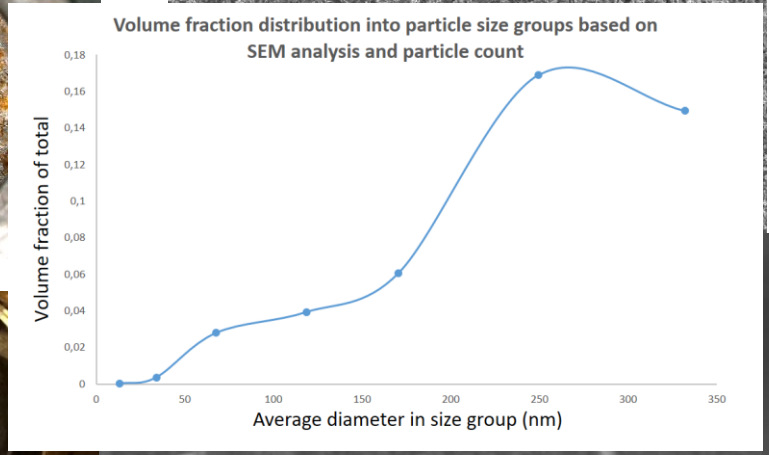


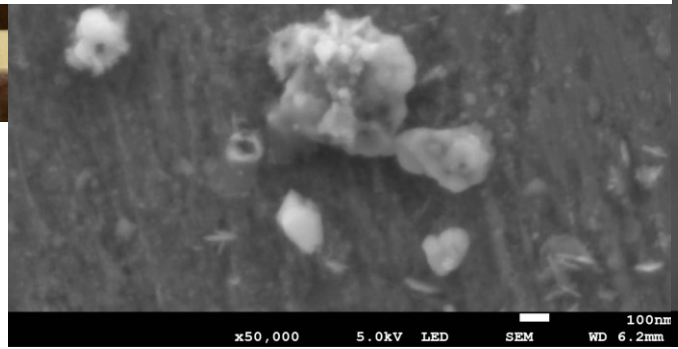


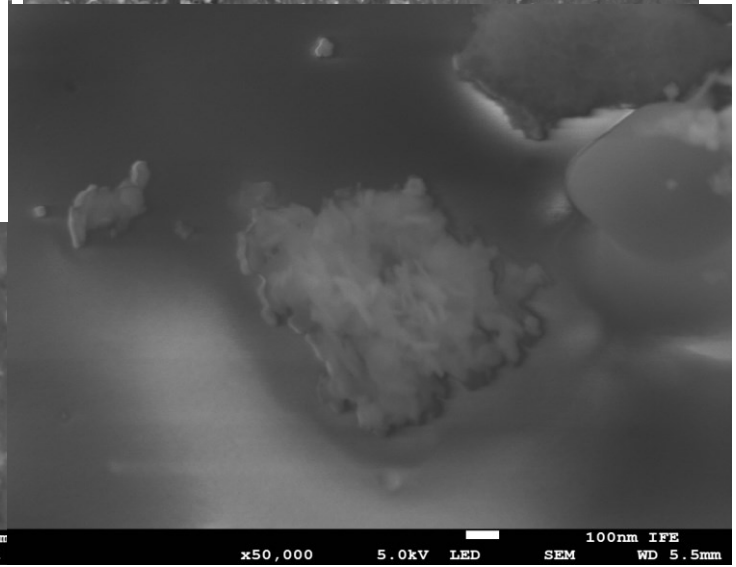
Photos of orifice











Measurements

- Tests were done for test pressures ranging from 76 to 150 bar and Reynolds numbers ranging from 1000 to 10 000
- Deposited material- differential weight of each test section before and after experiment
  - High relative uncertainties for the short duration tests
- Deposition rate in mg SiO_2 per surface area per second

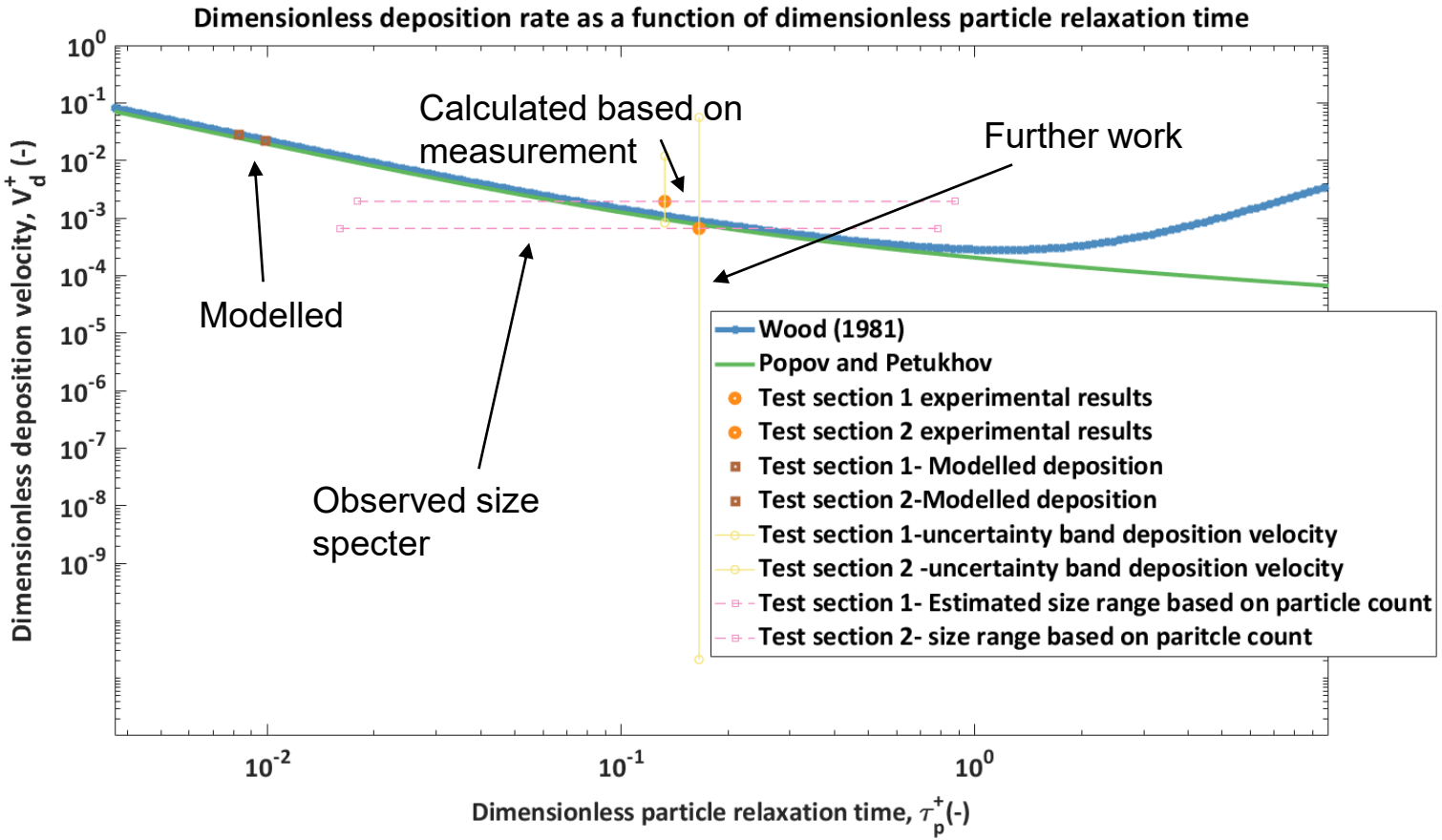
$$J = \frac{\Delta m}{A_{surface} \cdot duration}\left[\frac{mg}{m^2 s}\right]$$

$$V_d^+ = \frac{J}{c_{SiO_2} u_\tau} = \frac{\dot{m}}{c_{SiO_2} u_\tau A}$$

$$\tau^+ = \tau \frac{u_*^2}{\nu} = \frac{\rho_p d_p^2}{18\rho_l}\left(\frac{u_\tau}{\nu}\right)^2$$

Comparison of results

Test Pressure: 98 bar
Re:10 406



Preliminary Conclusions

- Most tests indicate a better fit with the observed average radius than the calculated radius
- Comparing the first and second test section, the relatively high measured deposition in test section two also indicate that the concentration will have had to be significant and therefore the previous deposition lower than expected
- No safe upper pressure for which silica will not precipitate above is indicated. Rather particle size and concentration is affected by the supersaturation
- The nature and predictability in modelling of the silica scaling process make controlled precipitation in the steam phase an interesting topic for further investigation in this HPHT case, as the energy gain can be significant compared to quenching in liquid to remove silica