Best practice for geothermal plants to minimize scaling and corrosion

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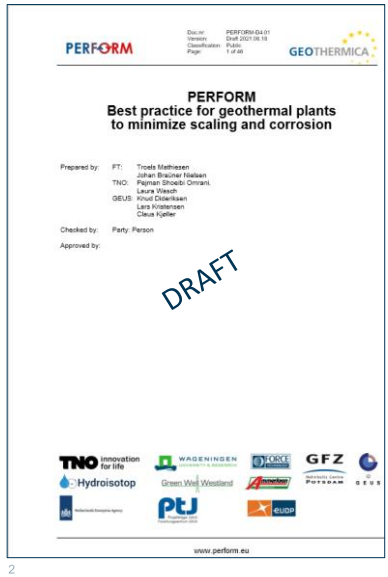
Best practice to avoid scaling and corrosion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Doc.nr: PERFORM-G4-01
Version: Draft 2021.06.18
Classification: Public
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GEOTHERMICA

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Best practice for geothermal plants to minimize scaling and corrosion

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DRAFT

TNO innovation for life, Hydroisotop, WAGENINGEN, Green Well Westland, FORCE, GFZ, GEUS, ptj, EUDP

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Background/scope

- Supplement to website toolbox
- Includes experience from entire PERFORM group
- Collects experience from operators in Danish, Dutch and German low enthalpy geothermal plants
- Questionnaire and interviews about challenges, current procedures and wishes for new guidelines

Main contents/chapters

2. Layout of geothermal plant and materials
3. Scaling and mineral precipitations
4. Corrosion in geothermal assets
5. Water sampling
6. Lessons learned from operation

Annex
Calculation of scaling index (LSI and RSI)
Trouble-shooting guide

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Several guidelines are already available

1. Comprehensive Danish guideline covering all phases from planning, including geology, risk analysis, commissioning, operation, legislation etc.
2. French catalogue of 20 datasheets covering details about well design, drilling, operation, corrosion inhibition, filtration etc.
3. Comprehensive Dutch guideline on materials selection using principles known from oil&gas.
4. Guideline on corrosion prevention in Danish plants.

PERFORM Best Practice builds on above and focusses on scaling, corrosion, water sampling and operational hints

Existing guidelines

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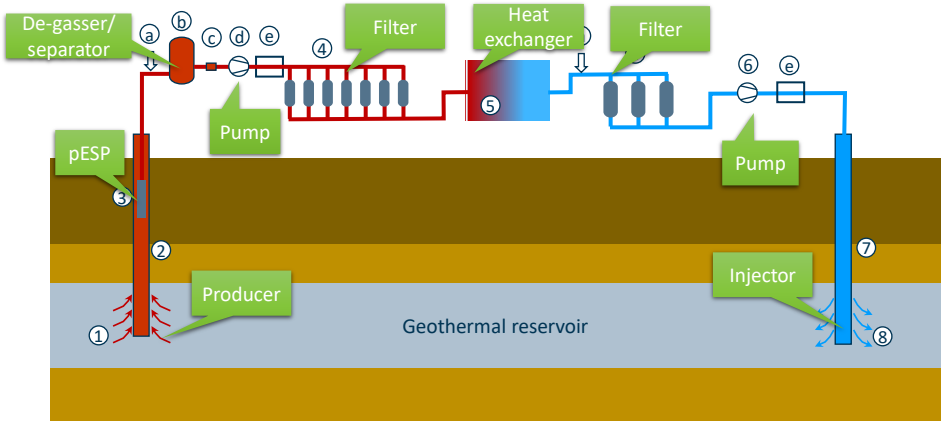
Basic layout of geothermal plants interviewed



Typical materials

Well tubing and piping:
Carbon steel (or composite)
Potential high release of rust in 3-6 km steel piping if corrosion isn't controlled

Pumps, heat exchangers, filters, instrumentation:
Stainless steel or corrosion resistant alloys (CRAs)

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Interview of operators

Top-3 headaches?

- Corrosion, why and where?
- ESP, increase reliability/lifetime
- Guidelines
  - Water sampling
  - NORM legislation

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Corrosion

Corrosion Types

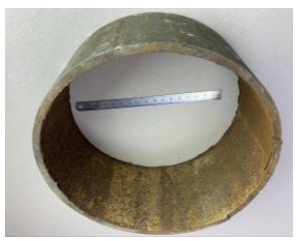
- What is the difference between pitting and uniform corrosion?
- What are the most corrosive elements in the brine?
- To what extent does corrosion release particles?

Corrosion control

- How can oxygen enter the system?
- Can CO_2 corrosion be stopped?
- Are dissolved noble metals a risk for corrosion?

Corrosion monitoring

- Why is side-stream loop preferred over intrusive probes?
- What are the pros and cons of the different probe types?
- What decides layout and configuration of a corrosion monitoring strategy?



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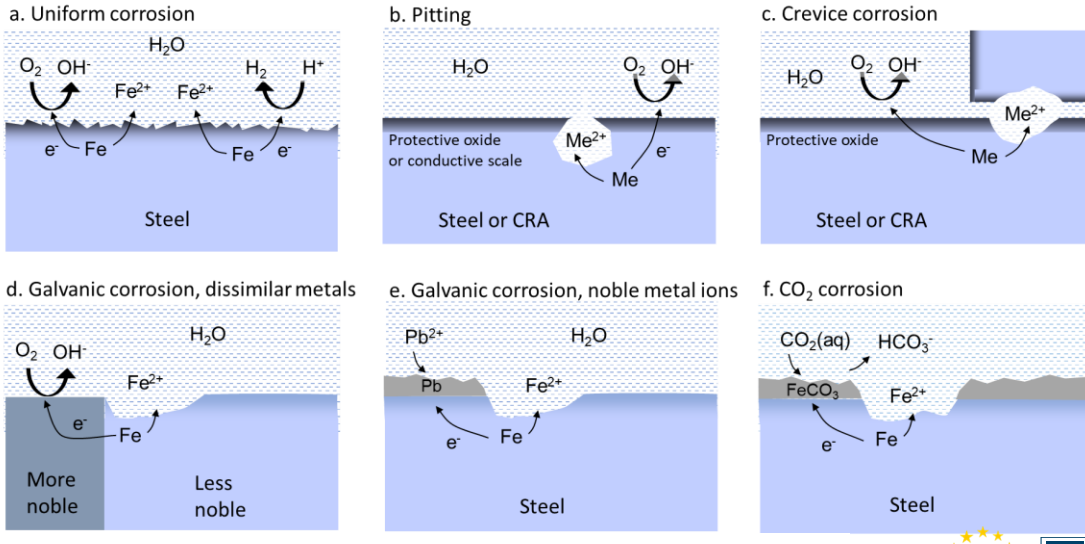
Possible corrosion forms



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Galvanic corrosion due to dissolved lead

- Brine from Bunter reservoir contains approx. 3 mg/l Pb++
- Galvanic deposition of lead corrodes the steel piping
- At least one leakage due to this mechanism
- Enormous range of galvanic element, L = 35 x diameter
- Lab tests show high susceptibility of steel, esp. at high temperature whereas stainless steel is unharmed by dissolved lead

$Fe \rightarrow Fe^{2+} + 2e^-$	anode / corrosion
Pb^{2+} $2e^- \rightarrow Pb$	cathode / driving force

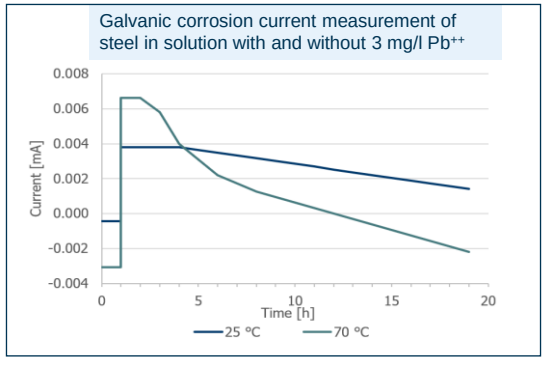

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Table 1. Common materials in contact with brine, and main considerations and concerns about their use regarding risk of corrosion.

Component	*Materials*	*Considerations / main concerns rg corrosion*
Producer, lower completion and producer (well bore)	Carbon steel for tubing	• Susceptible to corrosion driven by CO_2 or acidic components. • Susceptible to corrosion driven by dissolved noble metals (e.g. Pb, Cu). • Susceptible to corrosion by oxygen but it is hardly present in well. • If H_2S is present, special requirements apply to the steel material to avoid sulphide cracking. • Microbial activity (bacteria and archaea), but yet no reported cases of corrosion. • Be aware of surface condition. Mill scale should be removed because it otherwise can release large amounts of particles. • Consider adding a corrosion inhibitor to avoid above.
	Stainless steel EN1.4401, 316L for sand control screens	• Oxygen is the main risk, but hardly present in producer well. • Contact to carbon steel provides cathodic protection of the stainless steel. • If acids jobs or well workovers are performed, the potential damaging effects of the acid must be evaluated in advance.
	Composite (GRE)	• Corrosion resistant, but lower pressure rating and temperature rating than steel.

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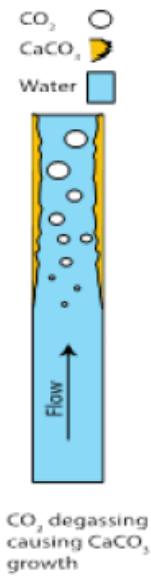
Scaling and mineral precipitations



Scaling Types

- Which type of scaling are observed in geothermal sites?
- What are the critical ions/minerals which triggers this mineral precipitation?
- What are the mechanisms and where do they occur in the plant?
- How can they be predicted?

Scaling Monitoring

- What indications can be used to monitor the scaling deposits and growth?
- Are there different methods to monitor the different type of scaling?

Scaling Mitigations

- What are the methods to mitigate each of these scaling precipitation?

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Annex II. Summary of Problems and Learnings

Identified problems linked to geothermal operations. Problems to be considered (and solved)	Suggested solutions – and methods developed for potential solutions through the PERFORM study work	Sites tested – and additional comments
Calcite scaling. Precipitation of calcite is a common problem. Calcite scaling is primarily related to CO_2 de-gassing or temperature increase. The solubility of calcite decreases as the temperature increases. Supersaturation with calcite indicates a potential risk of calcite scaling. A high downhole Saturation Index (SI) for calcite (SI > *c.* 0.3) points to potential scaling problems.	▪ Avoid CO_2 de-gassing by maintaining a **high operation (injection) pressure** that exceeds the bubbling point. ▪ Use **inhibitors** to keep Ca in solution. ▪ Use **cation filters** to remove Ca^{2+}. Such filters could e.g., be based on **seeded crystallization** (FACT filter*). The formed carbonate crystals are to be removed by filtration. ▪ Add CO_2 to the brine to prevent de-gassing (CO_2 control).	Generally, a challenge in plants with high CO_2 and Ca^{2+} content, for example Pijnacker-Nootdorp, Insheim, and Ammerlaan. ▪ Further lab. and field tests are needed for examining the FACT filter performance. ▪ Usually, the operators can handle this problem by pressurizing the system.
Barite scaling in the injection wells, the plant components or in the pores of the reservoir rocks. Pronounced barite scaling is observed at sites producing from hot, saline brines. Scaling with respect to barite is particularly a problem if the thermal water is super-saturated with barite, i.e., if the Saturation Index is high (> *c.* 0.5). The greatest risk occurs at the surface due to cooling (lower temp.)	▪ Use scaling inhibitors. ▪ Use **cation filters** with adsorption materials for barium removal (e.g., chitosan or zeolite) prior to re-injecting cooled water. ▪ Avoid site-locations with Ba-rich brines in the system, if possible. Avoid sites with $CaSO_4$-rich brines, as the stability of the $CaSO_4$ ion pair decreases significantly when the temp. is lowered, leading to $Ba^{2+} + SO_4^{2-} \rightarrow BaSO4$.	Margretheholm, Insheim, Horstberg, Den Haag, and Groß Schönebeck. ▪ Further lab. and field tests are needed for examining the effect and performance of the cation removal filters.

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Galvanic corrosion due to dissolved Pb^{2+} and Cu^{2+} in the formation brine. Especially pronounced if the chloride concentration > 100,000 mg/L. May lead to generation of metallic lead (Pb(0)) and copper (Cu(0)) in the geothermal wells.	▪ Use **particle filters** for removal of metallic Pb and Cu. ▪ Use **cation filters with adsorption materials** for removing Pb^{2+} and Cu^{2+} from the geothermal water (materials could be chitosan, Fe-oxide, and zeolite). ▪ Use corrosion inhibitors. ▪ Use tubings and casings made of corrosion-resistant material, e.g., casings of composite material. ▪ Use **corrosion-resistant alloys** to prevent (or limit) galvanic corrosion, e.g., stainless steels.	Margretheholm (Pb), Sønderborg (Pb) and Gross Schönebeck (Cu). ▪ Cation filters have been successfully tested in the laboratory – a field test is still needed. ▪ Carbon steel and several higher alloyed steels were tested in the lab. in order to examine/control the corrosion processes.

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Water Sampling

- Why is water sampling more complex for geothermal fluids?
- What should be analysed, and how often?
- Some components require analysis on-site, which?

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Selected facts from interviews of operators

Start-up	Precautions are taken to: - Minimize particles, flushing - Control degassing - Minimize seismicity, gradual start-up
Operation	Pumps - barrier sealing avoids air ingress - pressure control (>bubble point) to avoid wear and degassing Chemical dosage - 1-10 ppm (4/6) Monitoring - Corrosion (3/6) Water sampling - Monthly (NL), yearly (DE) or ad hoc (DK)

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Selected facts from interviews of operators

Shut-down	- Gradual reduction of pump to avoid seismicity (1/6) - Hydraulic separation of surface plant (5/6)
Standstill	- No circulation - No chemicals - Biocide and oxygen scavenger (1/6) - Pressurizing with nitrogen to avoid air ingress (3/6) - Depressurizing (vapor will avoid precipitation) (2/6) - Lubrication of ESP continues (1/6)
Well-head service (ESP)	- Replace every 3-7 years - Redundant pump on site - Argon blanketing or released gas for blanketing to avoid precipitation and oxygen ingress
Heat exchanger or heat pump service	- When scaling or leakages dictate it - Stainless plates are replaced with titanium - Heat pump serviced once a year (NL)

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Summary

The PERFORM project will soon release a new Best Practice focused on minimizing scaling and corrosion

Easily read introductions and advice are given to:

- Scaling and mineral precipitations
- Corrosion in geothermal assets
- Water sampling
- Operational hints from Lessons learned from operators

Join the MentiMeter later today to give your view on *Top 3 headaches* or need for *future research*

Thank you for your attention!

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