Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Þeistareykir Geothermal Field: Control of Scaling in Steam Gathering System and Reinjection Line.

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Keywords: scaling, aluminum-silicate, high enthalpy wells, reinjection, steam purity.

ABSTRACT

Some of the production wells in Þeistareykir geothermal field discharge high enthalpy fluid. The water-phase has low mineral content except for dissolved silica which is very high. During initial testing of the wells, scale formed in the test lines and clogged the flow measuring devices. This scale is formed above the saturation temperature for amorphous silica. The scale was found to be amorphous aluminum-silicate. Extensive tests were performed in order to optimize the design and operation of the steam-gathering system for the new plant. The tests showed that by operating the wells at high wellhead pressure and keeping the pressure high in the flow meter, the scaling was controlled, and the operation and flow measurement of the well were secured. Precipitation still occurred though in the steam-gathering lines which are operated at 9.5 bar (abs) pressure. During initial startup of the plant, dust particles from the dry wells entered the steam line. By mixing fluid from low-enthalpy and high-enthalpy wells before entering the separator plant, the particles were successfully washed from the steam, and clean steam was obtained. Tests were also performed which proved that the separator water could be safely reinjected after diluting it by condensate from the powerplant. No scaling has been observed in the reinjection lines after two years of operation.

1. INTRODUCTION

A new geothermal power plant with capacity of 90 MW was constructed by Landsvirkjun in the Þeistareykir geothermal field in north Iceland, Knútsson et al. (2018). The power plant has two 45 MW turbine units. Unit 1 was started in October 2017 and unit 2 in March 2018. 17 wells have been drilled in the field, and 10 wells were connected to the plant in 2018 (Figure 1). The production characteristics of the wells are different. Wells on C-pad are high in enthalpy and discharge mainly steam while the wells on A-pad are lower in enthalpy and discharge more water. The chemical composition of the brine from each pad is shown in Table 1.

Table 1: Chemical Composition of the Brine from A- and C-pad

		A-pad	C-pad
pH		8.94	8.97
CO_2	mg/kg	34.8	22.6
H_2S	mg/kg	25.2	30.6
SiO_2	mg/kg	678	1115
Na	mg/kg	123	114
K	mg/kg	22.6	25.1
Ca	mg/kg	0.39	0.32
Mg	mg/kg	0.008	0.006
Fe	mg/kg	0.008	0.005
Al	mg/kg	1.77	2.65
F	mg/kg	1.28	2.06
Cl	mg/kg	69	78.2
SO_4	mg/kg	26.6	9.5
B	mg/kg	1.03	2.86

The concentration of silica in the brine from the C-pad is much higher than from the A-pad. Aluminum, fluoride and boron are also higher. Sulfate is lower, but other chemical components are similar. During discharge testing, scaling occurred in the discharge-testing equipment of the wells on C-pad. This scale was found to be amorphous aluminum-silicate. Also, suspended solids were measured in the brine from some of the wells. Testing of scaling potential was therefore initiated in order to be able to optimize the layout and operation of the steam-gathering system and the reinjection system to control the scaling. During startup of the power plant, the steam contained mineral dust particles which were not washed out by the mist eliminators in the steam lines, Hauksson (2017 and 2018). This was dealt with by shifting part of the flow from the two-phase line connected to the low-enthalpy wells on the A-pad to the two-phase line connected to the high-enthalpy wells on the C-pad.

Figure 1: Þeistareykir steam field in 2018.

2. SCALING EXPERIMENTS ON C-PAD

An experimental grid for testing the effect of pressure on the scaling rate was constructed and connected to the wells on C-pad, Hauksson (2018). The grid consisted of four short test spools which were operated in parallel at different pressures (Figure 2 and 3). The pressure and flow in the spools were controlled by different sized orifices in and out of the test spools.

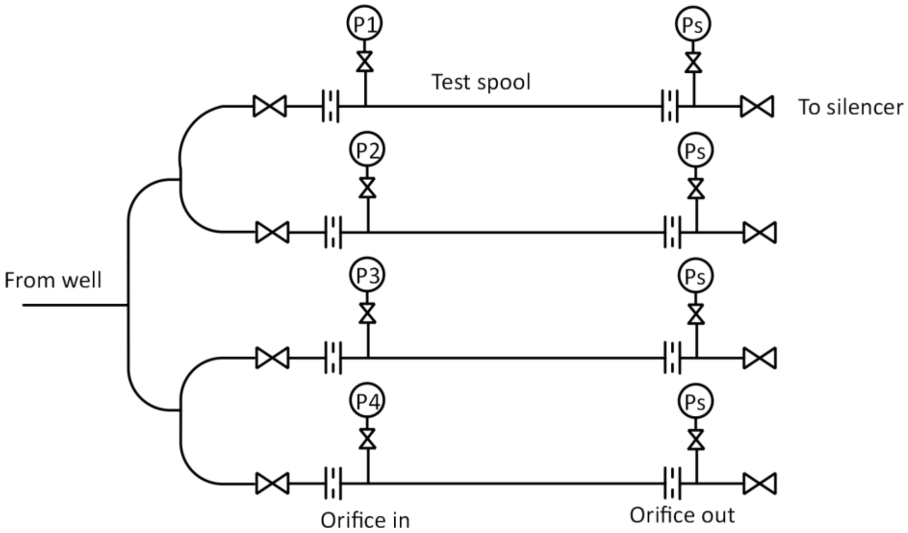

Figure 2: Experimental test grid with parallel test spools.

Figure 3: Test grid setup on C-pad.

Scale formed inside the orifices (Figure 4). The scale consisted of aluminum silicate, 82 w% SiO_2 and 10 w% Al_2O_3. The rest was Na_2O, K_2O and CaO. The scaling rate was dependent on the pressure in the test spool as can be seen in Figure 5. It was determined based on these results that 16 bar(g) pressure at 204 °C was needed to avoid scaling in the transfer line. The PN16 pressure rating of the two-phase transfer line did not allow such high pressures, the pressure was kept at 8.5 bar(g). At this pressure the brine becomes silica-supersaturated, and scaling is to be expected.

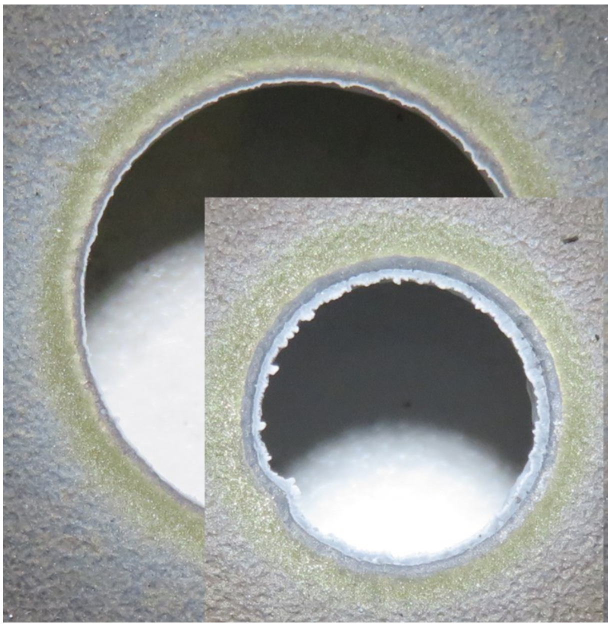

Figure 4: Scaling in 10-mm and 16-mm orifices.

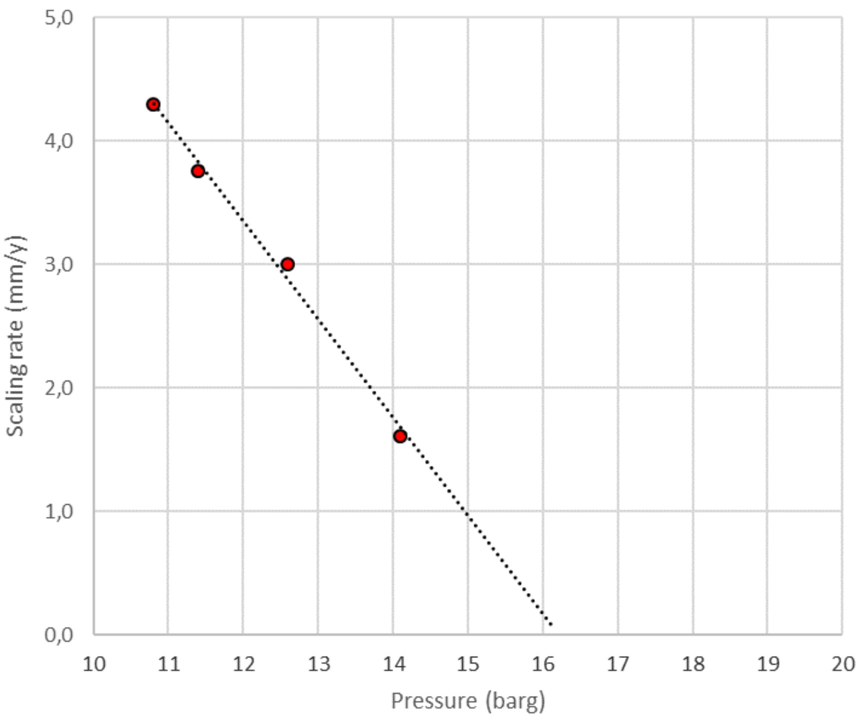

Figure 5: Scaling rate vs. pressure.

The proposed wellhead configuration was tested in a separate experimental setup which consisted of a pipeline with two different sections (Figures 6 and 7). The first section simulated a high-pressure spool at the wellhead where the pressure was kept high to avoid scaling in the orifice flow meter. The second section represented the brine and steam transfer line from well to the separator plant. The pressure in each section was controlled by orifices. This experiment confirmed that the high-pressure spool could be kept scale free and that the scale in the two-phase transfer line should be manageable. The two-phase transfer lines at the wellheads on C-pad were redesigned, and a short pipe section was kept at higher pressure to avoid scale buildup in the flow-measuring device. Also, a valve was put at the connection of the low-pressure section from the well to the main transfer line to enable disconnection of the section for cleaning.

After two years of operation, considerable scale buildup occurred inside the low-pressure section, while the high-pressure section was clean. The scale clogged the valve and isolation of the wellhead section for cleaning was therefore not possible. To clean the scale the complete two-phase line from C-pad to the separator station had to be disconnected. Although the scale can be cleaned by hydro blasting and is considered manageable, an alternative solution is being sought.

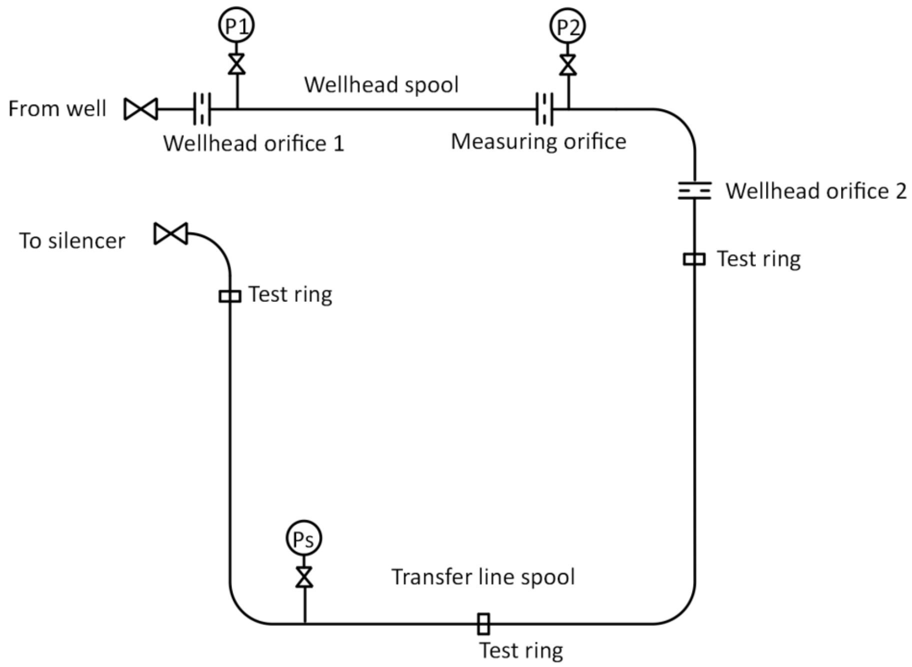

Figure 6: Experimental setup for testing of scaling in flowline sections.

Figure 7: Flowline test setup on C-pad.

3. SCALING EXPERIMENTS ON A-PAD

The brine from the separators is reinjected into shallow wells. To test for injectivity of the brine, the scale formation in brine and brine-condensate mixtures was tested, Hauksson (2016). An experimental separator was connected to two wells: well ÞG-05 which is low in enthalpy, and well ÞG-01 was is higher in enthalpy. The ratio of fluid withdrawn from each well was adjusted so that the mixture would represent the brine from all the wells in the field when the plant would be in full production. The fluid flowed through a grid with an orifice-battery and through a sintered-metal filter of 90-µm porosity (Figure 8). The orifice battery consisted of four orifices with small holes (Figure 9). The assembled battery is shown in Figure 10. The orifices were separated by gaskets and the flow was diverted between the orifices, which was supposed to simulate the flow of brine through narrow veins in the ground. The porous filter was supposed to simulate flow through pores in the rock. The brine contained 1 mg/kg of suspended solids which clogged the porous filter within an hour. It is therefore likely that the suspended solids will clog small pores in the rock and reduce the injectability in the long run. Dilution with condensate somewhat slowed down the filter clogging, but the pores are also expected to clog by diluted brine. Some scale formed on the face of the first orifice when undiluted brine was tested. The scale was made of particles which adhered to the surface when the flow was sufficient for the particles to penetrate the boundary layer at the metal surface. The scale was made of iron-, aluminum- and magnesium-silicates. The scale formation in the mixture of brine and condensate was negligible. Only a very thin layer of iron-sulfide formed on the surface of the orifices and very little of aluminum-silicate scale.

This mixture is not likely to clog the veins in the rock when injected. It was therefore recommended that the brine will be mixed with condensate before reinjection.

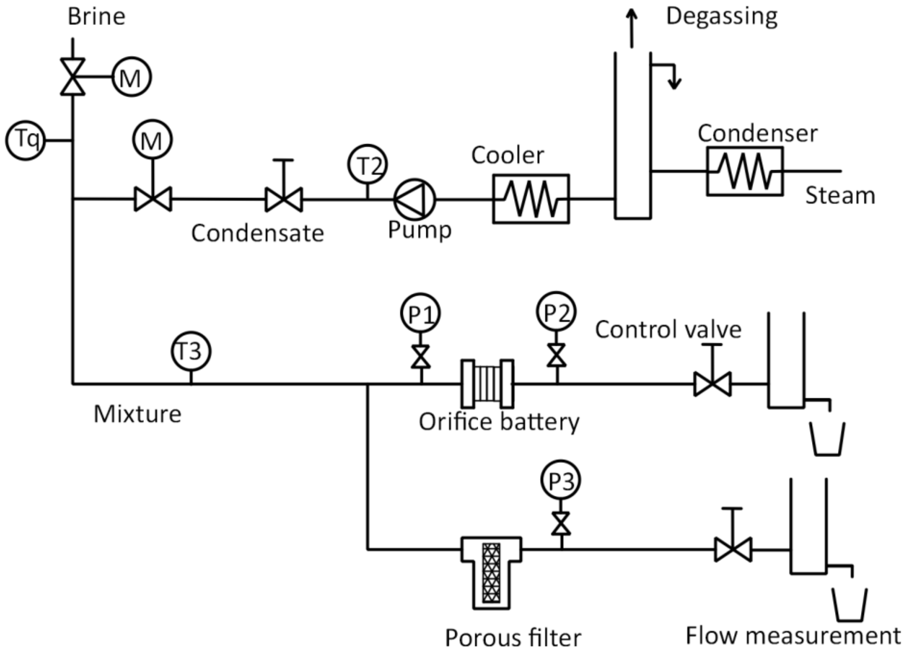

Figure 8 Testing grid for scaling in brine-condensate mixtures.

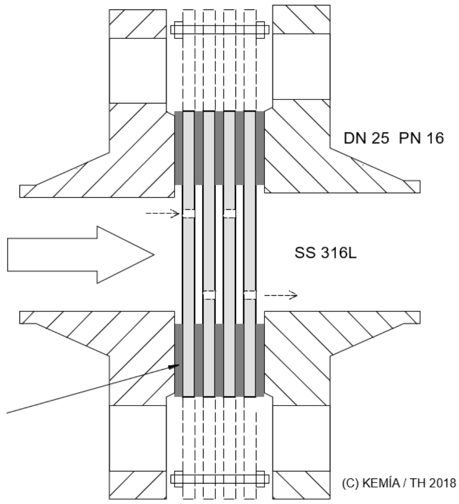

Figure 9: Drawing of orifice-battery.

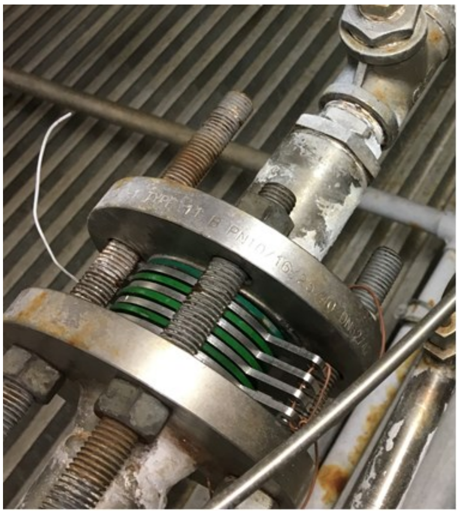

Figure 10: Assembled orifice-battery.

4. CARRYOVER OF DUST IN STEAM

The steam quality is monitored by the measurement of sodium (Na) in the steam. The samples are taken from the bottom of the steam lines just before the steam enters the turbines. The turbine manufacturer requires the concentration of silica (SiO_2) in the steam to be below 0.1 mg/kg. The silica concentration in the brine is six- to ten-fold the sodium concentration, and therefore the sodium concentration in the steam should not exceed 0.01 mg/kg to fulfill the manufacturer's recommendations. This was difficult to obtain in the beginning. The reason was that dust particles in the steam from the dry wells on pad-C and were not washed out in the mist eliminators in the steam line. By shifting part of the flow in the flowline from pad-A with low-enthalpy fluid to the flowline from pad-C, the particles were washed out from the steam. Figure 11 shows the measured concentration of sodium in the steam during the first year of operation. The flow was redirected in September and after that time the measured sodium levels were acceptable.

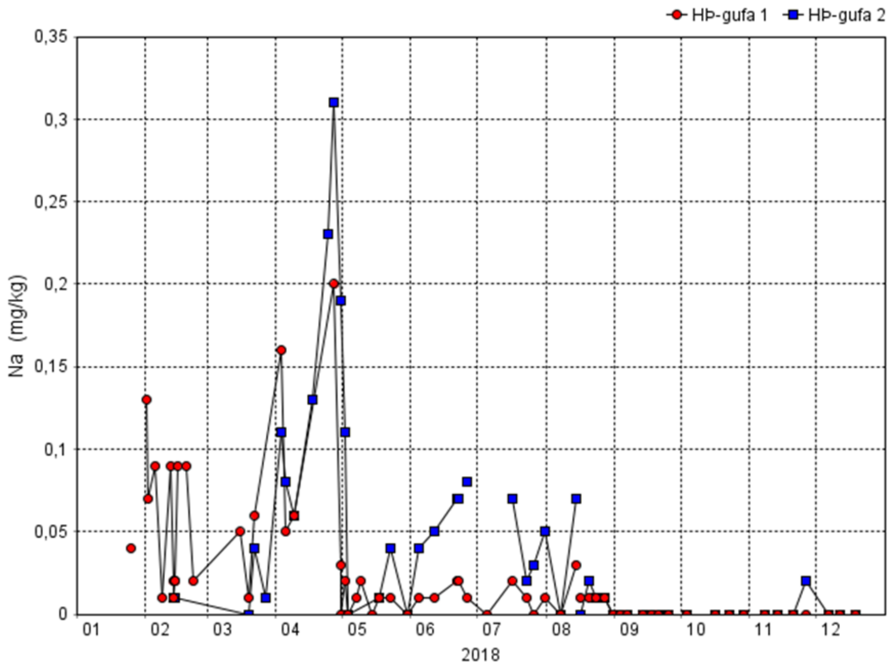

Figure 11: Sodium in steam during first year of operation.

5. CONCLUSION

By conducting scaling tests during construction phase of the Þeistareykir powerplant the layout and operation of the steam-gathering system could be optimized to minimize scaling in two-phase flowlines, reinjection wells, and turbines. Little scaling has been observed in the high-pressure wellhead lines and reinjection wells after two years of operation while scale buildup in the low-pressure two-phase lines from C-pad causes maintenance problems and still needs to be resolved.

6. REFERENCES

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