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Þeistareykir Geothermal Power Plant – Deposits in Gas Removal System.

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ABSTRACT

The National Power Company of Iceland, Landsvirkjun, has completed the construction of the Þeistareykir 90 MW geothermal power plant. Þeistareykir is in NE Iceland, 27 km SE of the town Húsavík. The power plant has been in full operation since April 2018. When operating a new geothermal Power plant, one might bump into various problems that are found to a lesser or greater degree at every site depending on the geology, reservoir conditions and chemical compositions. After only a few months operating condensate pumps in the gas removal system of Þeistareykir geothermal power plant started failing, closer inspection showed red-brownish deposits. Inspected deposits samples turned out to be mostly sulphur (S), selenium (Se), and partly oxygen (O) enriched products. Selenium and sulphur originating from volcanic activity as it is volatilized and transferred to the environment during volcanic activity. Later, expansion joint in the gas removal system started leaking because of corrosion, the reason being moisture and oxidizing conditions forming sulfuric (H_2SO_4) and selenic acid (H_2SeO_4)

1. INTRODUCTION

Þeistareykir power plant is a single flash power plant with two 45 MW turbine units. Unit 1 was started in October 2017 and unit 2 in March 2018. A flow diagram showing the operation in 2018 is shown in Figure 1, from Hauksson (2019). The geothermal fluids enter a separator, separating the fluids into saturated vapor and brine. The brine is diluted with condensate from the power plant condenser and injected into reinjection wells condenser. The vapor is transported to the turbines for electricity production. After the fluid exits the turbine, it continues to the condenser where the steam is cooled down converted to liquid through condensation. The condensate is pumped to the cooling tower. The NCG (non-condensable gas) is extracted through gas removal system.

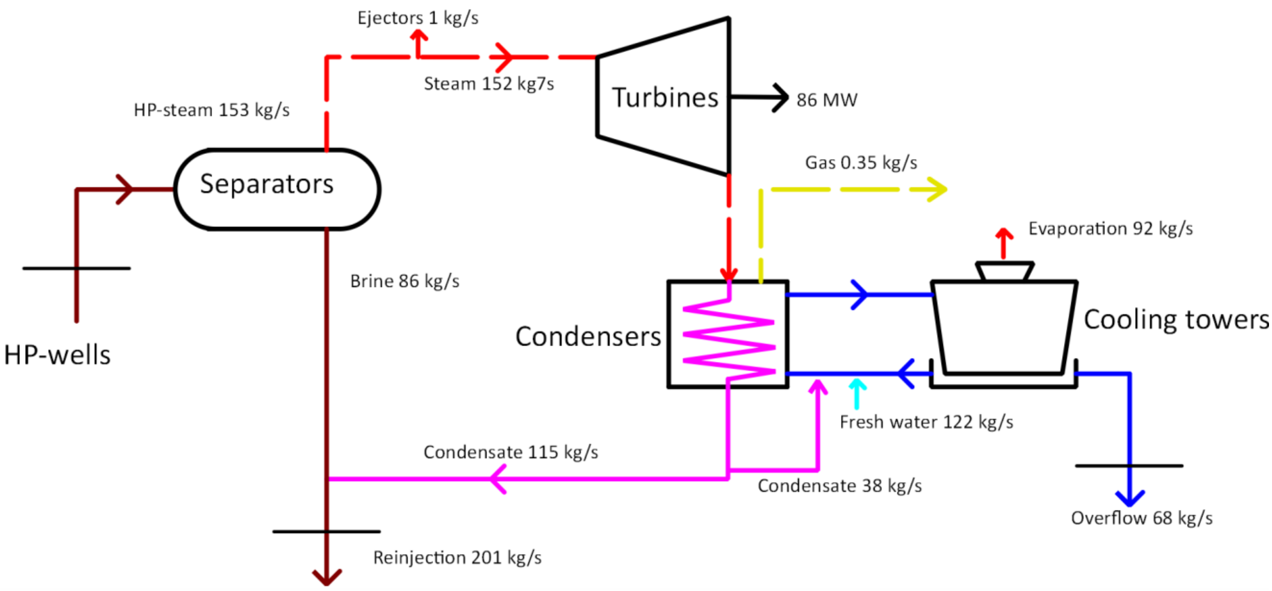

Figure 1: Flow diagram for Þeistareykir Power Plant in 2018.

After 18 months of operation leakage appeared in expansion joint in the gas removal system because of material failure, in continuation of that a warranty inspection of the Þeistareykir plant took place. This paper describes the experiences gained regarding the gas removal system of Þeistareykir the during the first years of operation.

2. OPERATING ISSUES IN GAS REMOVAL SYSTEM

The NCG (non-condensable gas) is extracted through gas removal system which consists of ejector, condenser, vacuum pump, condensate separator and condensate pumps. The gas removal system is shown in Figure 2.

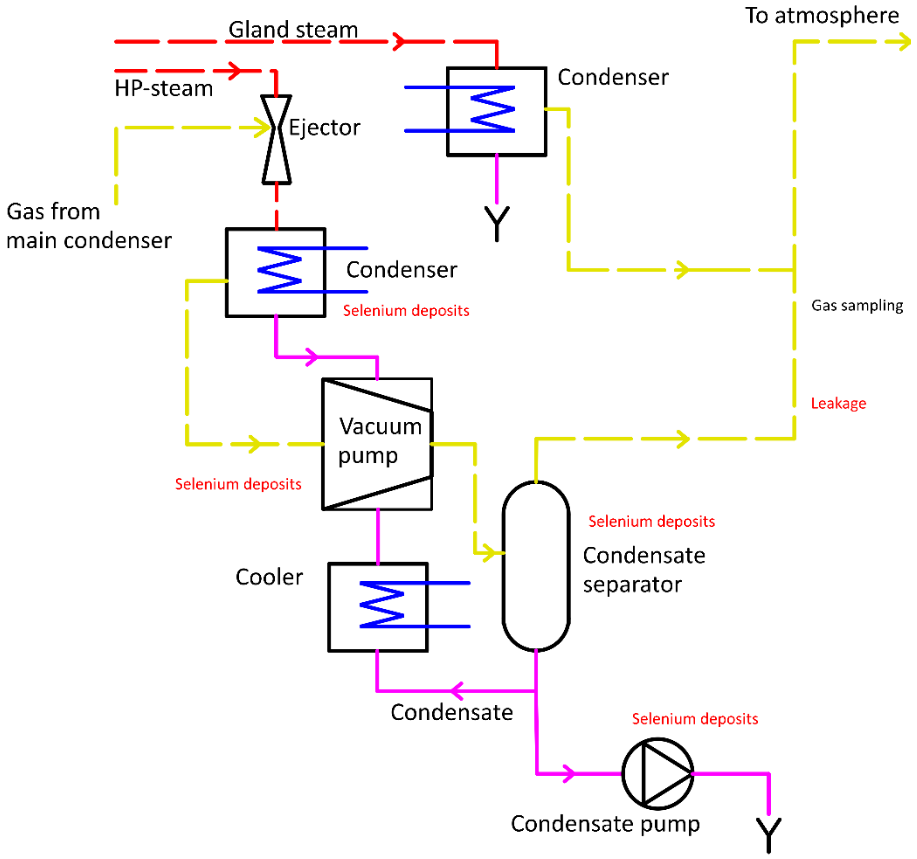

Figure 2: Flow diagram for the gas removal system.

In February 2018, after only five months of operation, problems appeared in condensate pumps in the gas removal system. The pumps were opened, and red-brownish colored scaling was detected, see Figure 3. The deposits were examined in electron microscope (SEM), see Figure 4. It consisted mainly of small particles (< 10 µm) made of selenium (Se), sulfur (S) and carbon (C). Scattered in the substance are particles and filaments made of iron (Fe), nickel (Ni) and chrome (Cr), presumably stainless-steel particles, Hauksson (2018a).

Figure 3: Selenium deposits in condensate pumps of the gas removal system.

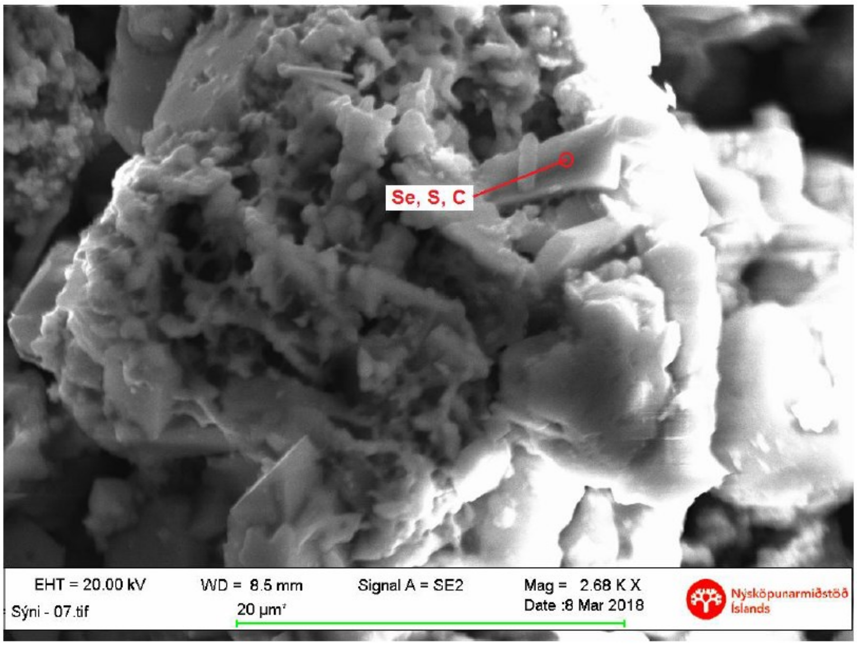

Figure 4: Electron microscope picture of selenium deposits.

To find out the origin of the selenium, gas samples from steam entering the turbines and gas exhaust from the turbines were analyzed for selenium content. Selenium can be transported as a gas in the form of H_2Se, Symonds and Reed (1993). The gas was collected in alkaline solution which absorbs acidic gases such as CO_2 and H_2S as well as H_2Se. The CO_2 and H_2S was analyzed by titration. Portion of the alkaline sample was analyzed for selenium. Samples of steam entering units 1 and 2 from separator stations, and gas samples from exhaust stacks of units 1 and 2 were analyzed for selenium (Se) and arsenic (As), Hauksson (2018b). Samples were first oxidized by the addition of 2% H_2O_2. The ICP-SFMS analyses were carried out according to SS EN ISO 17294-1, 2 (modified) and US EPA Method 200.8 (modified). The results for Se and As are shown in following table calculated as volume fraction of hydrides in the gas, Hauksson (2018b).

Table 1: Selenium and arsenic hydrides in steam and exhaust gas.

Site	Fluid	Time	H_2Se	AsH_3
			vppm	vppm
Separator 1	Steam	2018-02-20	6	<0,3
Separator 2	Steam	2018-02-14	<10	<0,4
Exhaust 1	Gas	2018-02-14	3	<0,4
Exhaust 2	Gas	2018-02-14	1	<0,4

The values of Se and As are low for all the samples. Slightly higher values for hydrogen selenide was determined in the incoming gas than in the exhaust. The arsine in the gas was below detection limits in all the samples. Analysis of gas composition of steam entering the turbine and in the gas exhaust is shown in Table 2, from Hauksson (2019). Detecting the selenium in the steam in the separators support that it originates from the geothermal wells.

Table 2: Composition of gas in steam and gas exhaust in unit 1.

	NCG	CO_2	H_2S	H_2	O_2	N_2	CH_4	Ar
	l/kg	vol%	vol%	vol%	vol%	vol%	vol%	vol%
HP-steam	1.38	53.8	26.3	18.2		1.2	0.35	0.09
Exhaust gas		48.5	24.5	19.1	0.42	7.3	0.05	0.11

3. WARRANTY INSPECTION

After 18 months of operation, leakage appeared in expansion joint after condensate separator in the gas removal system where non-condensable gases are extracted (Figure 2). During warranty inspection of the plant, surface samples of scaling and corrosion products were collected. Red deposits were found in many locations of the gas removal system, also in some areas yellow deposit was noted. In the first stage diaphragm of turbine number one, scale was detected consisting mainly of Si and O indicating that it is mainly composed of silica (SiO_2) Přikryl et al. (2019). The silica scale is expected to have formed in early 2018, in that period there where difficulties in cleaning dust particles from dry wells in the mist eliminators due to lack of brine causing carryover. This was solved by letting brine rich fluid from another pad mix with the dry wells fluid before entering the separators.

Samples retrieved from the gas pump has a reddish appearance, Figure 5. When inspected with SEM/XEDS, the sample shows the presence of S, Se, C solids with low oxygen content (≤ 1.5 wt.%), see Figure 6. Similar observations are generated from Figure 6B, except slightly higher O (≤ 5.91 wt.%) and Fe (≤7.6 wt.%) and additionally Mo (≤ 4.9 wt.%), indicating also presence of corrosion products. Inspected scaling sample are mostly S, Se, and partly O enriched products, Přikryl et al. (2019).

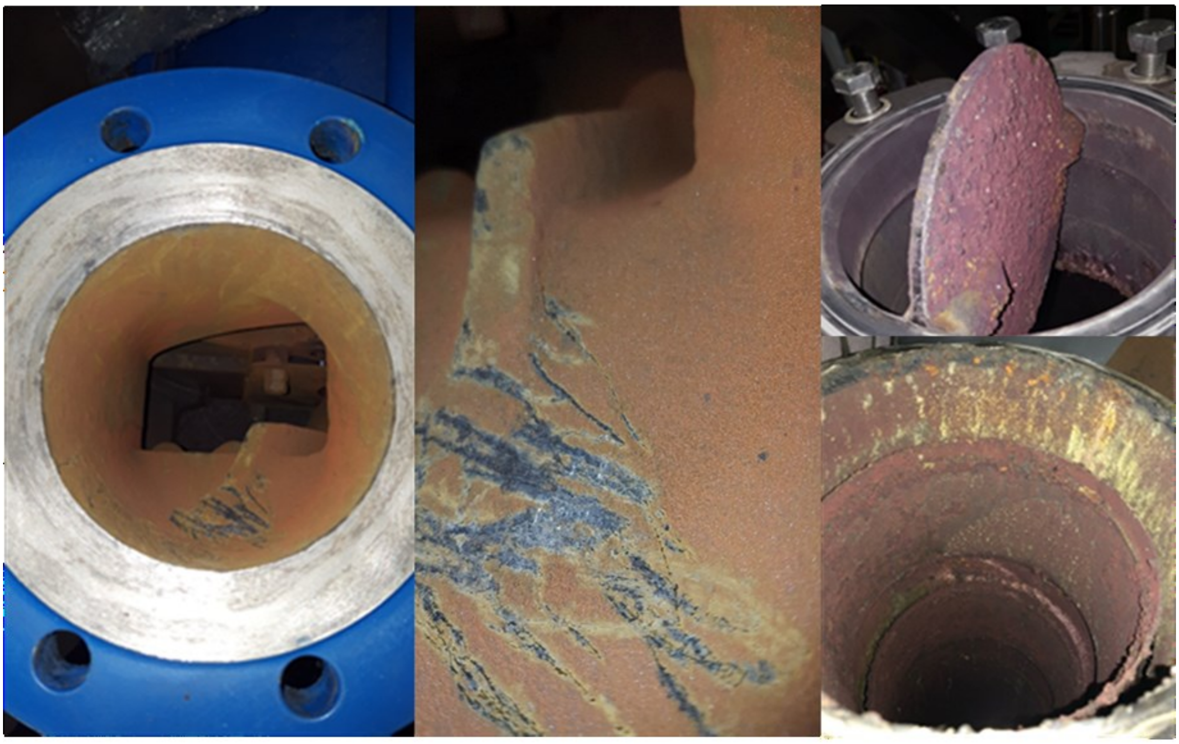

Figure 5: Deposits inside gas removal system.

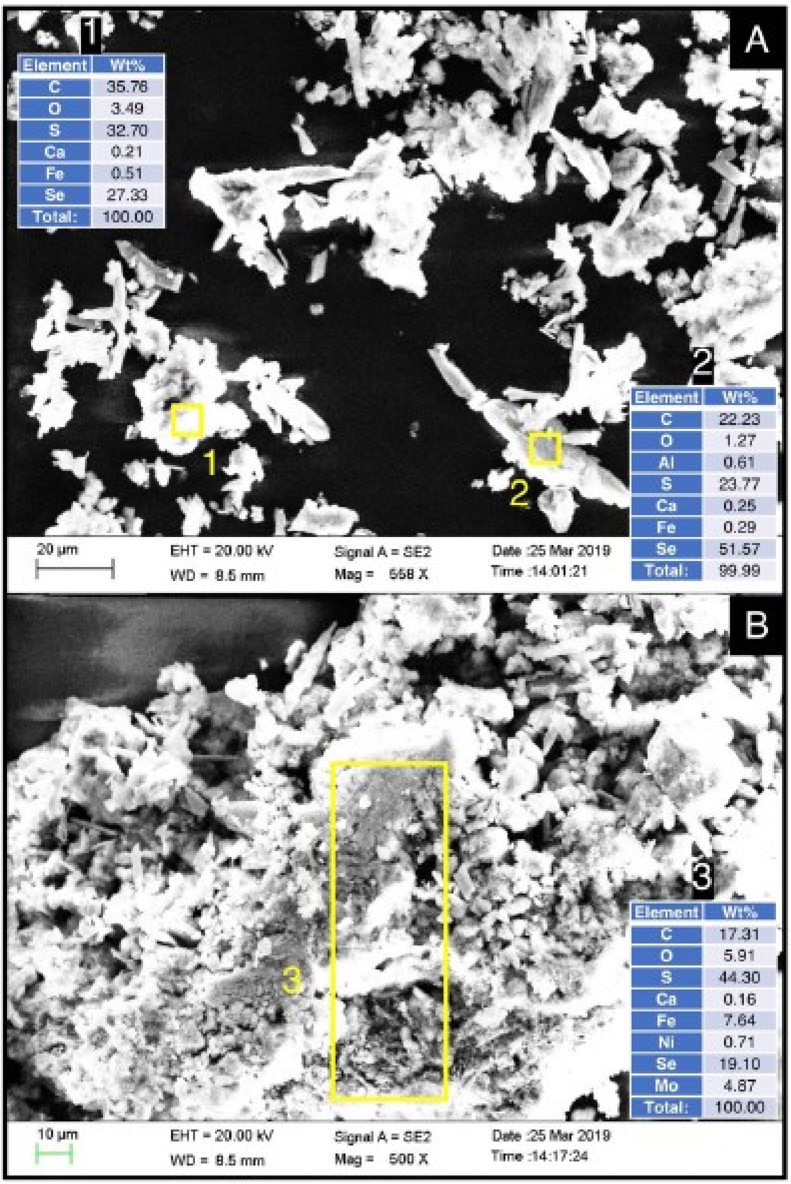

Figure 6: Analysis of deposits from the gas removal system.

4. CONCLUSIONS AND DISCUSSION

Inspected scaling samples in the gas removal system are mostly S, Se, and partly O enriched products.

Separator units are exposed to harsh conditions with high moisture content, where the S and Se are a serious corrosion threat, something that is obvious in visual inspection showing heavy scaling and corrosion products. However, hydrogen sulphide and sulfur species were found to be the dominant corrosion agent for the obtained samples overall. Introduction of additional oxygen due to the failed material, as in the case of expansion joint, will increase the rate of corrosion with formation of selenic acid and sulfuric acid. Eliminating the O_2 content would most likely decrease the corrosion damage, Přikryl et al. (2019).

To prolong the lifetime of the expansion joint, a higher grade of the material is needed that is resistant to sulphur induced stress corrosion cracking. Despite the low temperature of the gas entering the joint, between 25-35°C, the other components in the environment; high H_2S concentration, moisture, presence of oxygen and tensile stresses are enough to induce severe corrosion effects, Přikryl et al. (2019).

As the selenium is detected in the geothermal fluid, Hauksson (2018) it's origin must be of volcanic origin. Previous studies have looked at the selenium relationship to volcanic activity as it is volatilized and transferred to the environment during volcanic activity. Ólafsson and Riley (1978) reported Se concentration in geothermal water in Reykjanes with range 0,46-0,83 µg/L but on the other hand Higgins and Roberge (2007) reported Se content in volcanic rocks from 1973 eruption of Eldfell volcano with range 2.17-3.69 mg/kg. As selenium is below sulfur in the periodic table, these elements have similar chemical properties. Despite that the gas from the geothermal field has much higher H_2S concentration than H_2Se, in these conditions that take place in the gas removal system Se is more unstable and precipitates.

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