



Mineral scaling in two-phase geothermal pipelines: Two case studies



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ABSTRACT

Mineral scaling is a common problem in geothermal power facilities. This scale deposition is usually caused by changes in the geothermal fluid temperature or composition and chemistry. Precipitation of minerals can limit fluid flow within the steam field equipment, reducing plant efficiency and increasing maintenance costs.

A layer of scaling is commonly found in most parts of the geothermal steam gathering system. However, significant amounts of deposited mineral scales are usually observed in the pipelines and vessels that handle silica super-saturated brines.

This work focuses on a less common scaling in geothermal two-phase pipelines, when fluids are usually high enthalpy and under-saturated with respect to amorphous silica. The scaling is mainly caused by mixing and changes in steam fraction at the two-phase pipelines, when several wells share the same pipeline header to transport the fluid to the downstream facility.

Two case studies are discussed in this work reporting mineral scaling due to the mixing of incompatible geothermal fluids within two-phase headers.

The first case investigates silica deposition caused by the mixing of a steam-dominated well fluid with fluid from two water-dominated wells. The scale deposition is caused by the small amount of brine entrained in the steam-dominated well fluid, which reacts upon mixing with the fluid from the other water-dominated wells, causing massive localised scaling at the mixing points. The second case investigates iron sulfide and silica deposition caused by the mixing of a low-pH, high-silica fluid with neutral-pH fluid.

Header blockage can result in an increase in wellhead pressures causing production from some wells to collapse, at the same time decreasing the flow of geothermal fluids to the separators. The scaling requires regular cleaning to return the pipelines to full flow capacity. Recommended engineering solutions are given for both cases, for possible site implementation.

1. Introduction

1.1. Mineral scaling in geothermal environments

Deep underground fluids transfer geothermal energy to the surface for utilization (Barbier, 2002). The reservoirs that host these fluids can currently be accessed by drilling wells from the surface down to a few kilometres (Gupta and Roy, 2006). The extracted fluid is then conducted through pipelines where it is used to generate electricity, commonly by separating the steam component of the fluid and running it through electricity generating turbines.

The chemistry of a geothermal fluid is dependent on variations in temperature, gas content, heat source, rock type, rock permeability, age of the hydrothermal system and fluid source (Barbier, 2002). In some cases, the composition of a fluid can vary within the same geothermal

systems or the same well.

A frequently encountered challenge during geothermal energy production is mineral scale deposition in wells and station infrastructure. When highly mineralized geothermal fluids are extracted, they are subject to changes in temperature and pressure. This can lead to the supersaturation with respect to one or more minerals causing deposition which leads to problems in pipelines and power plant equipment.

1.2. Scaling in geothermal power stations

Mineral deposition can occur at any point within the geothermal power station. Following the path of the fluid upon reaching the surface, changes in temperature may lead to mineral supersaturation that can cause scaling. A decrease in pressure can also lead to the release of

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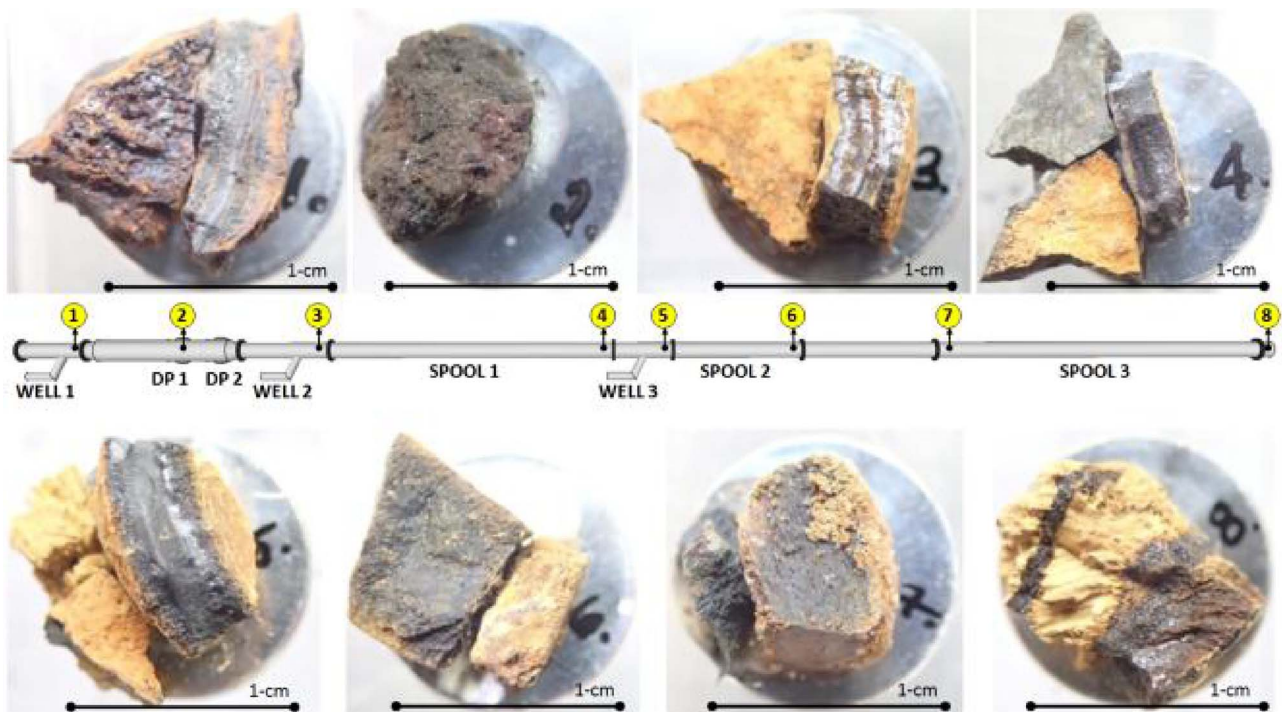


Fig. 1. ESEM-EDS samples and their corresponding locations on the pad A two-phase header.

dissolved gases from the fluid, changing its component concentrations and pH, also leading to scaling. When fluid is moving along pipelines to different parts of the power station, mineral precipitation reactions may take place and deposit scale along these pathways. Tassew (2001) showed the common locations for the different mineral scales encountered in a typical single flash geothermal power production system. This includes calcite scaling in production wells; silica scaling in the separator, water drum, effluent disposal pond, turbine nozzles and re-injection wells; and sulfur deposition in condensers and cooling towers.

Mineral scaling in surface infrastructure will lead to the loss of capacity for the pipelines, vessels and equipment, which, in turn, will decrease the efficiency of the geothermal plant (Phillips et al., 1979). Furthermore, if the scaling is extensive, a shutdown may be required to clear the lines and equipment to return the plant to full operation (Villaseñor and Calibugan, 2011). This increases maintenance costs and reduces the plant capacity.

Deposition can also occur within the vessels holding fluids supersaturated with respect to certain scale minerals (e.g. silica). Geothermal separators and holding tanks can be expected to have some scaling due to the large volumes of fluids they normally hold, allowing longer residence time for scale to form. Turbines can also experience scaling when brine carry-over occurs in the steam. In binary power plants and direct use applications, mineral scaling is commonly found in the heat exchanger (e.g. Scheiber et al., 2015). Heat exchanger tube fouling commonly occurs because of the significant drop in temperature along the length of the tubes. It increases the thermal resistance of the walls and decreases the available pipe diameter, both detrimental to the efficient utilization (Zarrouk et al., 2014).

1.3. Scaling treatment methods

For efficient operation of plant, scale deposition must be mitigated or controlled. The feasibility and success of a treatment method is typically site specific (Formento, 2012). This is due to their effectiveness being dependent on the physical properties and chemical composition of the geothermal fluid.

Many methods have been investigated for the prevention and

mitigation of mineral scaling in geothermal facilities. The usual method of scale removal is through mechanical scraping. Commonly, acid is being added before scraping and the scale removed by pressure washing (Phillips et al., 1979). Note, however, that this method is for removal of existing scale deposits. This is a maintenance issue and is scheduled on a regular basis.

For scale control, Phillips et al. (1979) categorized treatment methods into: inhibitors (which retard the growth of scale); alterants (which change the chemistry of the geothermal fluid); and coagulants or flocculants (which remove suspended particles from the solution). The selection of the best treatment method is dependent on a combination of the need to prevent scaling and the avoidance of effects on the temperature and flow rate of the fluid. Engineering design can also be used to collect scale deposits where they can be removed (Van Rosmalen, 1983).

By determining the chemical composition of the geothermal fluid before production, the possible type and extent of scaling can be predicted. This is necessary to determine what methods to implement to resolve the problem. Thorough testing of an inhibition method is also needed to determine its appropriateness within the plant. It is important to note here that; this is only possible after the drilling and testing of the geothermal wells.

In this study, two examples of scaling are described from the Leyte geothermal field, the Philippines. The scale is mainly encountered during mixing of geothermal fluid from different well in the two-phase header, when it is undersaturated with respect to amorphous silica. We demonstrate that the scale is related to the formation iron sulfide (pyrite, pyrrhotite, magnetite and hematite) which cannot form an equilibrium assemblage. It is likely that the scales in both pads formed under different conditions such as would result from reduced access of sulfur species caused by the scaling. Engineering solutions are given for both example cases to prevent the formation of scale.

2. Scale evaluation methodology

Representative scale samples were collected at different locations along two-phase header lengths (Pad A and Pad B). The samples were

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