

Significance Of The Pressure Let Down Station In Mitigating Effects Of Silica Precipitation In Steam Pipelines: A Case Study Of Olkaria 280MW Project

Joseph Chumari and Daniel Odongo

Kenya Electricity Generating Company PLC

jchumari@kengen.co.ke; dwanga@kengen.co.ke

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ABSTRACT

A pressure let down station is a set of equipment that allows a geothermal system to change the operating pressure of the steam gathering system to a higher point and still maintain the power plant inlet pressure at the designed point.

In 2012, KenGen began construction of two geothermal power plants; 140M We Olkaria IV and 2 additional units 4 & 5 (140M We Olkaria IAU) thereby increasing power generation in Kenya by 280M We. The two power plants have turbine inlet pressures of 6.0bara and 5.0bara for Olkaria IV and Olkaria IAU respectively. This meant the steam gathering systems would also operate at that pressure.

While construction was in progress, a new optimization study reported that the deeper wells in Domes, East and North East fields which serve the power plants with steam would tap fluids from reservoirs that are rich in silica. The issue was compounded by high enthalpies of the wells averaging 1790kJ/kg to 2300kJ/kg thereby increasing silica solubility and chances of precipitation in steam pipelines (Mannvit, 2012)

This concern resulted in KenGen incorporating Pressure Let down Stations in the two power plants that would maintain the steamfield pressure at the maximum but within the constraints of the already selected equipment, and then expand the steam to drop its pressure to required values. It was also not feasible to incorporate a topping plant because the project was already at an advanced stage and most of the equipment was already designed and even manufacture started for some. Venting was ruled out since it was not good practice bearing in mind wastage of steam.

This paper will use the case study of these power plants to highlight the significance of the Pressure Let-down Stations in scaling down effects of silica deposition in steam gathering systems.

1. OVERVIEW, OPTIMISATION, SILICA AND HIGH ENTHALPIES

The greater Olkaria Geothermal field is located in the southern part of the Kenyan rift about 120km North-West of the Kenyan capital, Nairobi.

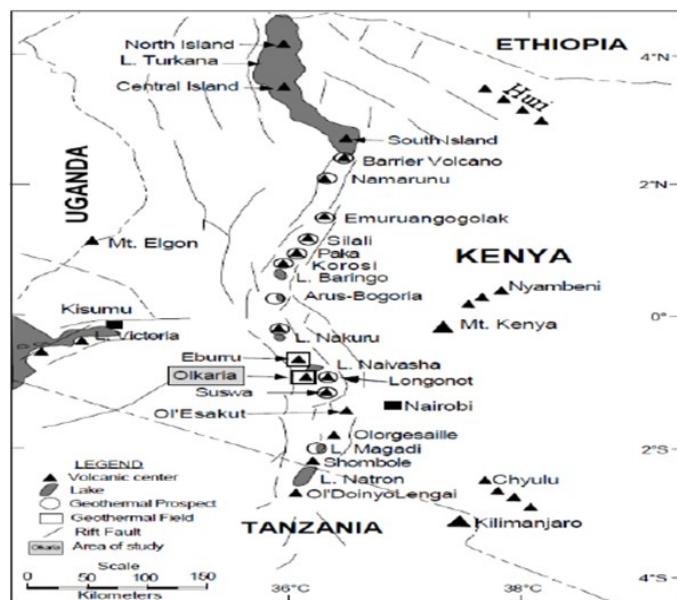


Figure 1: Map of the Greater Geothermal Area within the Great Rift Valley of Kenya

KenGen PLC operates five power plants in Olkaria with a combined output of 790M We and 20 wellhead steam turbine generator units with a total output of 83.0M We.

The 280M We power plants are served by production wells in the Domes area (Olkaria IV) and East and the North East field (Olkaria IAU) drilled to depths of between 2800m and 3010m. Scaling is a common problem in geothermal processes; in particular it occurs from brines where minerals become saturated and precipitate. In Olkaria, amorphous aluminous silica (AAS) scaling has for example resulted in decommissioning of OW-34 separator station and subsequent steam and brine pipelines.

To prevent scaling, geochemists use thermodynamic modelling to apply appropriate treatment methods such as adjusting temperature and/or pH. Generally, the thermodynamic properties of the minerals and the aqueous species involved in the chemical reactions are used. When adequate data is unavailable, an accurate assessment of scale formation becomes problematic.

The design concept of the steam gathering system for the 280M We project was based on the recommendations by the feasibility study report by Westjec, 2009.

In the feasibility study report by Westjec, 2009 and which was the basis for inception of the 280M We project, observed that the potential for silica scaling for wells within the Olkaria resource area would vary from well to well because the resource temperatures range from a low of 240°C to a high of 340°C. In addition, Westjec, 2009, observed that there was mixing between the upper and deeper production feed zones and this would result in excessive boiling which would increase silica saturation levels. Westjec, 2009 also noted that well tapping from the higher temperature reservoirs would have higher risks of silica saturation and scaling.

Westjec, 2009 recommended separation pressures for the new wells based on historical observation from the existing Olkaria I & II production fields. The recommended separation pressure was between 4.5 to 5.0bara and based on the wells with minimal silica scaling over the years, only some wells were an exception and for those wells separation pressures of 7bara had to be maintained due to higher silica levels and higher discharge enthalpies.

As a result, Westjec, 2009 recommended separation pressures of 5.0bara for the new wells within Olkaria I & II fields and 6.0bara for the wells drilled within the domes field. In addition, Westjec, 2009 based their recommendation for separation pressures of 5.0bara for wells within Olkaria I&II fields because the existing steam network was operating at a separation pressure of 5.0bara therefore it would be convenient to use the same pressure rating when steam was to be shared between the existing and new power plants .

For Olkaria Domes, Westjec, 2009 considered separator pressures ranging from 2, 5, 7, 10 and 13bara. Westjec, 2009 then analyzed the potential productivity of the wells based on their optimum outputs. From the analysis, Westjec, 2009 recommended a separation pressure of 6bara for the wells in domes field.

In the report for the Feasibility of Additional Generating Power Plants (Report No. 9), Mannvit, 2012 noted that selection of the optimum separator pressures would take into account of;

1. The thermodynamic optimum,
2. Well productivity curves and
3. Chemical constraints, in particular, silica scaling

Mannvit, 2012 explained that the chemical constraints depend on the reservoir temperatures and to avoid silica scaling, separator pressure should be selected high enough to prevent silica super saturation in the geothermal fluid. Mannvit, 2012 presented the recommended minimum separation pressures for given reservoir temperatures. This is summarized in Table 1:

No.	Resource Temperature in °C	Recommended Minimum Separation Pressure in bara
1	240	3
2	260	6
3	280	10
4	300	15
5	320	21

Table 1: Minimum Separation Pressures per Resource Temperature

To ensure that the original power plant interface steam flow rates and operating pressures remained unchanged, a permanent solution would be to operate the steamfield at high pressure, and to install throttling devices (pressure let-down valves) near the power plant interface. Olkaria IAU would operate at 11.2bara and Olkaria IV at 11.6bara. The installation of pressure let-down valves at the steamfield power plant interface, however, would result in superheated steam at 170°C in Olkaria IV and 166°C in Olkaria IAU. This exceeds the allowable limit of steam dryness and maximum steam superheat of >99.8% and <2.5°C respectively for the interface of the two power plants.

There was a range of different approaches to addressing this issue all with different implications. KenGen PLC elected to implement a permanent solution whilst delivering on-specification, saturated, low pressure steam to the turbines.

2. SOLUTION

2.1 PRESSURE LET-DOWN STATION

There are four steam pipeline at the interface of each of the two power plants from individual separator stations.

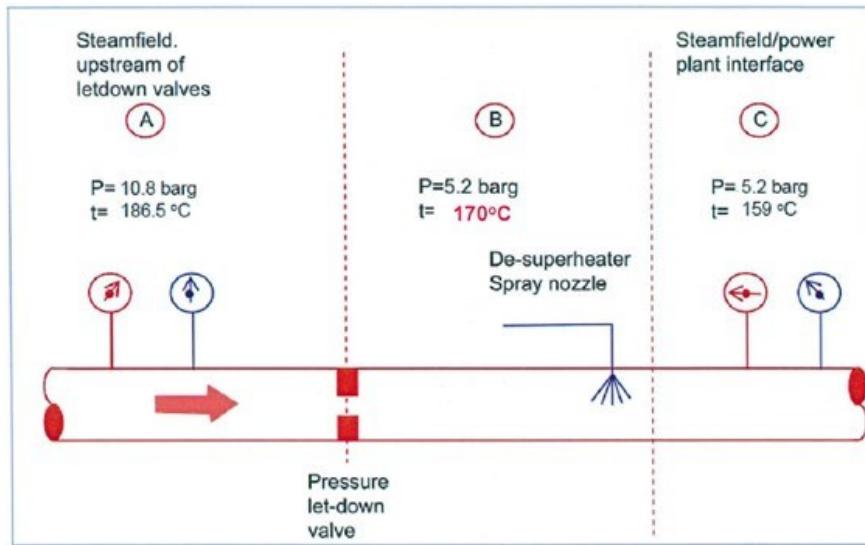


Figure 2: An illustration of the PLDS in one of the four steam pipelines in Olkaria IV

Each of the four steam pipelines running through the pressure let-down station contains;

- A DN500 segmented ball type with noise attenuating trim and pneumatic actuator (Figure 3),
- An in-line silencer to reduce noise to acceptable levels (Figure 4) and
- Condensate drain pot to collect excess water injected into the system (Figure 5)



Figure 3: An illustration of let-down valve removed during annual inspection

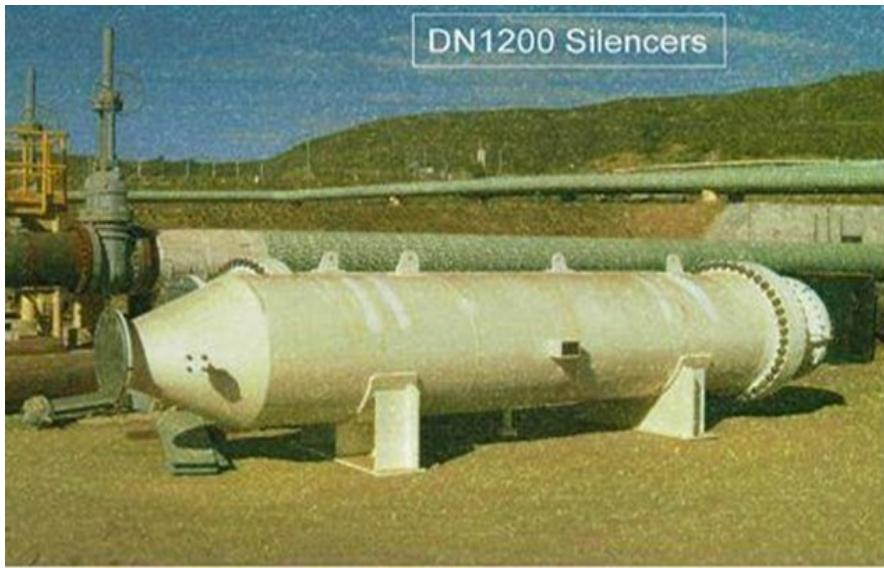


Figure 4: One of the silencers prior to installation



Figure 5: One of the CDPs with a level control system in Olkaria IAU

The overall pressure let-down station comprises of the four steam pipeline system valves and a de-superheating water (DSW) system applying ratio flow control loop.

High pressure steam is supplied at nominal pressure of 11.6bara and 11.0bara and reduced to 6.0bara and 5.0bara at the power plant interface via the PLDS in Olkaria IV and Olkaria IAU respectively.

2.1.1 De-superheating System

The enthalpy of steam upstream of the let-down valves is the same as the enthalpy of steam downstream of the let-down valves. With reduction of steam pressure after the let-down valves, the steam becomes superheated.

Downstream of the PLDS, de-superheating water (DSW) which is power plant condensate can be injected into the steam piping to achieve near saturation steam conditions at the power plant interface.

Pressure	6.0	bar absolute
Specific Enthalpy of Superheated Steam (h)	2783	kJ/kg
<input type="button" value="Calculate"/> <input type="button" value="Reset"/> <input type="button" value="Print"/>		
Superheat Temperature	170.232	°C
Saturation Temperature	158.826	°C
Degrees Superheat	11.4054	°C
Specific Enthalpy of Water (h _f)	669865	J/kg
Specific Enthalpy of Evaporation (h _{fg})	2.08577E06	J/kg
Density of Steam	3.06708	kg/m ³

Figure 6: Data from the steam tables showing the superheat temperature

The DSW system consists of supply, storage, pumping and distribution elements with pressure level and flow controllers.



Figure 7: DSW pumps in Olkaria IAU

Excess water can be injected to maximize the opportunity for the steam and water to reach equilibrium before the liquid has to be removed from the system via the interface CDPs or the power plant scrubbers, and to prevent dry out of the impurities in the water.

An excess wetness value may be selected by the operator. The design water injection rate targets 1% excess wetness above that required for saturated steam. This water injection rate corresponds to 180% of the water flow rate required to achieve saturated conditions.

2.1.2 DSW Supply

Water for the suction of the DSW pumps can be taken from either the power plant condensate circuit (hot well pump discharge) or a raw water tank. The primary source was to be the power plant condensate as this water has low dissolved oxygen and relatively low dissolved solids.

Water pressure was to be measured by a transmitter located on the suction header of the pumps. If the condensate supply pressure were to fall below the set point, the raw water tank discharge valve would open, allowing water to be supplied from the tank, thus allowing uninterrupted flow of water to the de-superheating system in the event of power plant condensate pressure reduction. The liquid pressure available at the power plant interface was to be at 0.8barg

2.1.3 DSW Pumps

At the Olkaria IV and Olkaria IAU interfaces, 3×50% pumps supply water to the de-superheating spray nozzles via flow control valves.

The set point for the water flow control has a minimum allowable value corresponding to the minimum flow requirement for the nozzles and to prevent damage to the pump.

The Olkaria IV and Olkaria IAU interfaces DSW pumps are each sized to deliver 50% of the normal required flow of 19M Ton/hr (Olkaria IV) and 23M ton/hr (Olkaria IAU)

If one duty pump fails or trips, the standby pump has been configured to start without manual intervention.

2.1.4 DSW Injection

At the Olkaria IV and Olkaria IAU interfaces, $3 \times 50\%$ pumps supply water to the de-superheating spray nozzles via two parallel flow measurement and control systems (one for each power plant unit). Each flow controller modulates the duty FCV to achieve the required water flow set point to provide wet steam to the power unit.

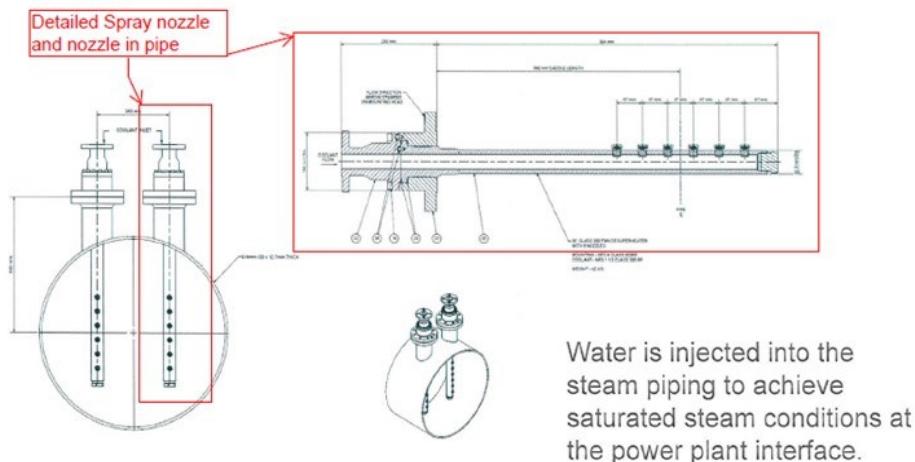


Figure 8: Arrangement of a pair of nozzles in one of the pipes

2.1.5 Condensate Drain Pot Level Control

Four condensate drain pots (CDPs) were installed at the interfaces of both Olkaria IV and Olkaria IAU immediately upstream of the steamfield interface with the power plant. A level transmitter and high-level switch were installed on each condensate pot.

During normal operation the steam will be wet and the CDP has been designed to operate full, water flows like a fine mist over the pot and up the vertical legs. During low steam flows, the velocity may not be sufficient to carry water up the vertical leg hence a water level must be maintained in the pipe. This introduces a risk at low flow that a water slug may form, potentially causing damage to the piping or the scrubber downstream.

To prevent this from occurring, a level transmitter has been set to open the level control valve (LCV) installed on the drain pot to maintain the level within the pot. A high-level switch has been set to open the LCV to maintain the level in the drain pot.

3. CONCLUSION

The pressure let-down station provided a temporary reprieve for KenGen PLC to allow the steamfield to be operated at a higher pressure without necessarily changing the design that would have been expensive in terms of time and cost. This solution can be used for steamfields that experience change in reservoir conditions and still need to run an existing plant. The control system developed was simple to integrate to the existing system and maintenance costs are low.

With the PLDS in place, the Olkaria 280M We steamfield has experienced low silica precipitation that was evident during planned inspection of the separator vessels, throttling valves and brine re-injection systems.

4. ACKNOWLEDGEMENT

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