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Neutralization of Acid Fluids from Well H-43 (Superheated Steam), Los Humeros Geothermal Field, Mexico.

Heber Diez, Magaly Flores, Miguel Ramírez, Rigoberto Tovar, Cesar Rosales, Felipe Solano and Fernando Sandoval.

Alejandro Volta # 655 Morelia- Michoacán- México

heber.diez@cfe.gob.mx

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ABSTRACT

Production well H-43 was drilled in the northeast area of the Los Humeros geothermal field from October 21, 2007 to January 18, 2008. There were at least seven production wells drilled in the area during the 1980's, with similar conditions to well H-43. These wells were eventually abandoned, because of the highly corrosive nature of their fluids. The wells showed low pH values in the discharge fluid, which was attributed to the presence of gaseous hydrogen chloride (HCl). This ionizes in the presence of humidity to form hydrochloric acid.

In the case of well H-43, analysis of discharge chemistry showed a pH value of around 3 with HCl gas content. The well provides approximately 35 tons per hour of superheated steam (30°C superheat) at wellhead pressure of 40 barg (580 psig) and wellhead temperature of 285°C. This thermodynamic condition of the well present an opportunity to operate and connect the well to the production system, because the superheat ensures that the HCl gas remains in a dry environment , thereby preventing corrosion of the well production casing and surface facilities. The well has been supplying steam to the power plant since May 2013 with an acid inhibition system installed in the pipe system, which is discussed in this paper. The successful utilization of H-43 opens the possibility of exploiting wells with similar acid characteristics, representing approximately 200 MWe of power generation potential in this part of the reservoir.

1. INTRODUCTION

Well H-43 was drilled from October 21, 2007 to January 18, 2008 in the northeast area of Los Humeros geothermal field located in the state of Puebla, Mexico; Figure 1 shows the location of H-43 in the field. Other seven production wells were drilled during the 1980's, with similar chemical condition to H-43 and abandoned due to highly corrosive nature of their fluids. These wells showed low pH values in the discharge fluid which was attributed to the presence of gaseous hydrogen chloride (HCl), that ionizes in the presence of humidity to form hydrochloric acid.

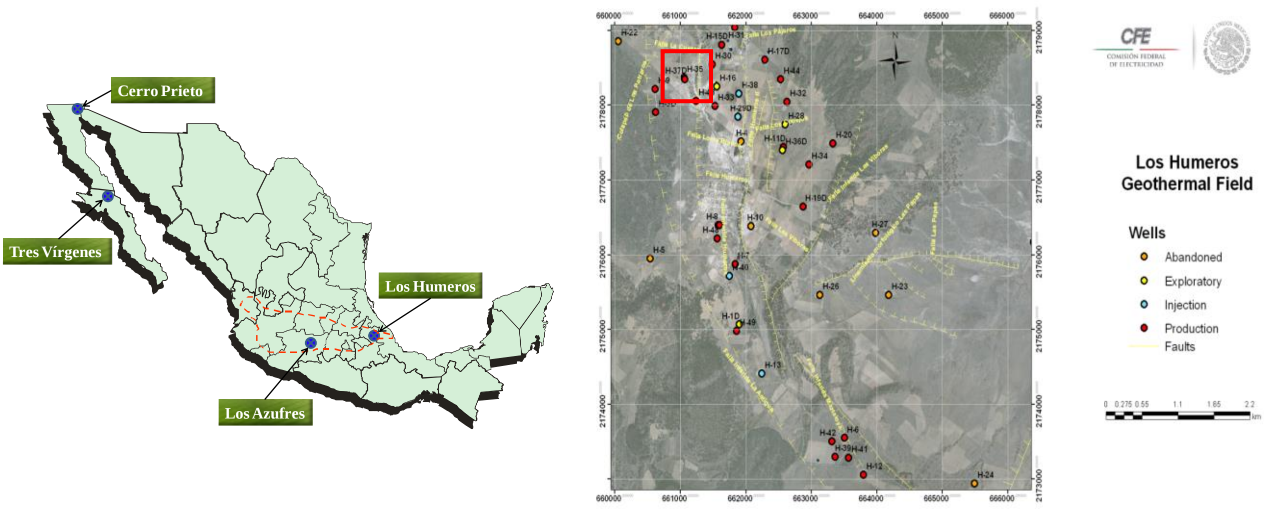

Figure 1: Well H-43 in Los Humeros Geothermal Field, Mexico.

Production well H-43 was tested after drilling and showed an acidic discharge with pH around 3. This suggested the corrosive nature of the discharge that could affect the condition of the well and the wellhead surface facilities. This highly acidic condition was confirmed by chemical analysis of samples of condensed steam from H-43, as summarized in Tables 1 and 2 below. The samples were taken with the well operating under an orifice plate of 50.8 mm (2") in diameter. Laboratory analysis also confirmed excess chloride (Cl^-), which is attributed to presence of HCl in gaseous form. This led to the conduct of test design to neutralize HCl and take advantage of the acidic fluid from the well.

Table 1: Chemical composition of the condensed steam (Cruz and Tovar: 2008).

Well	pH	Electric Conductivity (µS/cm)	Total Alkalinity (meq/liter)	Cl	B	HCO_3	SIO_2	SO_4	Na	K	Ca	Mg	As	Fe
				mg/liter (ppm)										
H-43	4.47	145	0.4266	31	958	1.67	21.95	45	0.58	0.36	0.55	0.04	9.11	8.21

Table 2: Percentage on weight of gases, (Cruz and Tovar: 2008).

Well	Gas Total (% W_T)	Ar	CH_4	CO_2	H_2	H_2S	He	N_2	NH_3
		%Wi							
H-43	3.86	0.7645	0.0134	84.31	0.3995	9.62	0.00	4.8908	0.0041

The design to initially neutralize the acidity was based on the wells saturated thermodynamic condition that was in agreement with the initial production characteristics of the well, taken from downhole pressure and temperature measurements. A solution of sodium hydroxide (NaOH) was injected into the well through incoloy tubing that was set at 1350 m below the production casing completion (Flores et al, 2010).

The acid neutralization tests were carried in 2009, 2011 and 2012 that showed successful acid inhibition. However, there were also a number of challenges encountered during the tests which occurred in the delivery system of the acid inhibitor. One of which was the loss of the Incoloy tubing in 2011 test.

The last test showed scales of crystallized sodium carbonate in the wellhead, this was observed that is formed under superheat condition. This superheating condition was confirmed later from the wellhead pressure and temperature data. This would mean that the NaOH inhibitor was not adequate for using under those conditions. Those scales were so considerable that obstructed the valves of wellhead.

The formation of the scale was due to the reaction of NaOH with the steam at superheated condition. The chemical composition of the scale is described below which was obtained from X-Ray diffraction analysis.

- Natrite (sodium carbonate, Na_2CO_3).
- Thermonatrite (hydrated sodium carbonate, $Na_2CO_3 + H_2O$).
- Possible traces of NaCl.

A decision was made to use an inhibitor composed of potassium carbonate (K_2CO_3) + AMINE, which has some advantages over NaOH solution and has more tolerance to the level of superheating of the fluid (Weres and Kendrick 2010).

2. WELL H-43 THERMODYNAMICS.

An atmospheric discharge test was designed in 2011, to attempt to retrieve the lost tubing inside the well. Thermodynamic information was also obtained during the discharge test that corroborated the level of superheat at different well opening conditions. Figure 2 shows the plot of well temperature and pressure obtained during the atmospheric discharge together with the saturation temperature at wellhead pressure condition, and the corresponding degree of superheat of the fluid. Figure 3 also shows the pressure and temperature data plotted in the Clausius-Clapeyron curve as well as the values corresponding to the different production orifices plates. The plot corroborated the condition of the well, to be located in the region of superheated steam.

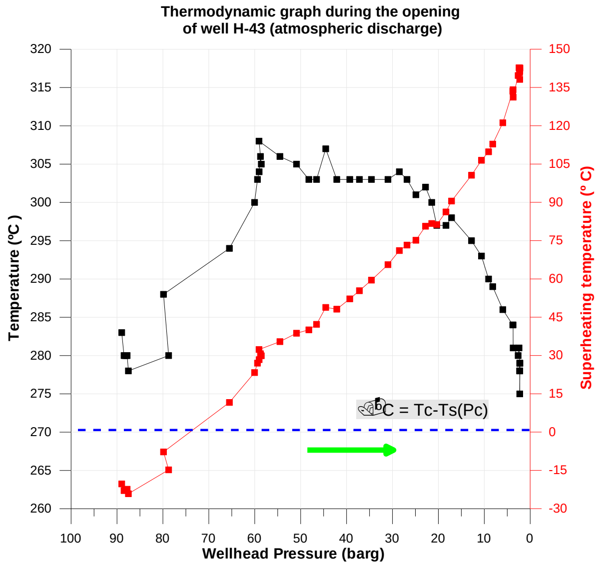

Figure 2: Thermodynamics Conditions during the flow test of well H-43 (atmospheric discharge, Diez 2013).

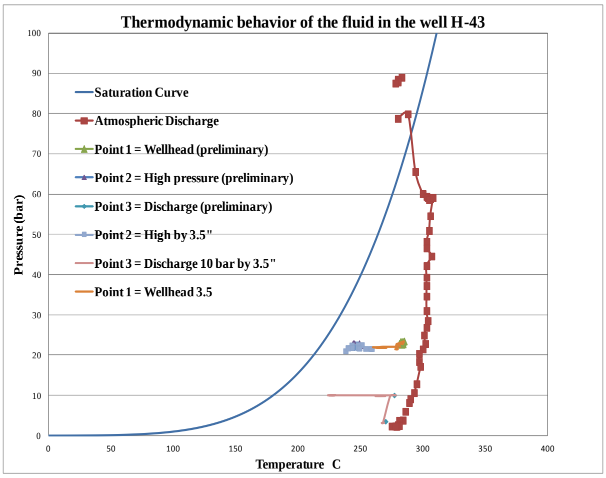

Figure 3: Thermodynamics behavior of fluid in well H-43 (Diez; 2013).

From the graphs shown above it was determined that the fluid was steam with at least 35°C of superheat, at integration conditions to the electricity generation system.

3. NEUTRALIZATION OF HYDROGEN CHLORIDE

As noted earlier, the primary corrosive agent is hydrochloric acid; which is caused by the ionization of gaseous hydrogen chloride. The superheat condition of the fluid also ensures that no corrosion is occurring inside the wellbore, and the neutralization process can be simplified and conducted in the surface as indicated in Figure 4 below (Hirtz et al., 1991).

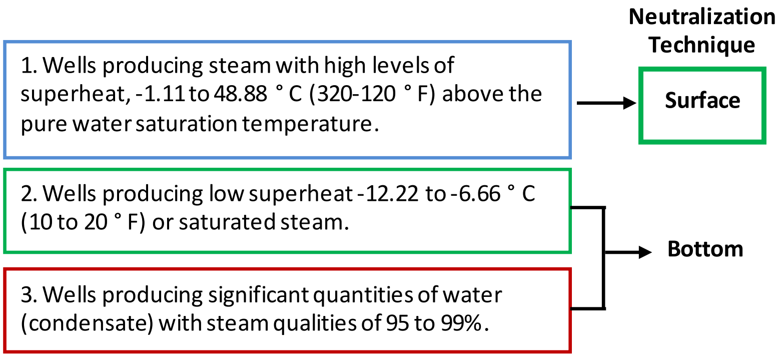

Figure 4: Classification of wells to define the neutralization technique by thermodynamics.

3.1. Operating conditions

Well H-43 should be operated under a known and constant condition that allows the analysis of all the variables involved, so it was decided to operate the well with an orifice plate of 50.8 mm (2") diameter as shown in Table 3.

Operating conditions, well H-43.	
Orifice plate	50.8 mm (2") diameter
Estimated production	34 t/h of Superheated steam
Wellhead pressure	40 barg (585 psig)
Wellhead temperature	285°C
Superheating	30 °C

Table 3: Operating conditions, well H-43.

3.2 Thermodynamics analysis in pipes system

Up to this point it was only necessary to determine where the thermodynamic saturation of the steam from the well H-43 could occur, or where this steam could find humidity in the pipe reticulation system. The energy losses through heat transfer were calculated after the orifice plate. It was determined that the energy losses were minimal that the steam would still be in superheated condition once it reaches the interconnection to the steam gathering system. Hence, it is anticipated that no corrosion should occur along the steam gathering pipeline, so long as the superheated steam will be maintained. This would mean that neutralization should be near the pipeline interconnection to address potential corrosion with changing thermodynamic condition as shown in Figure 5.

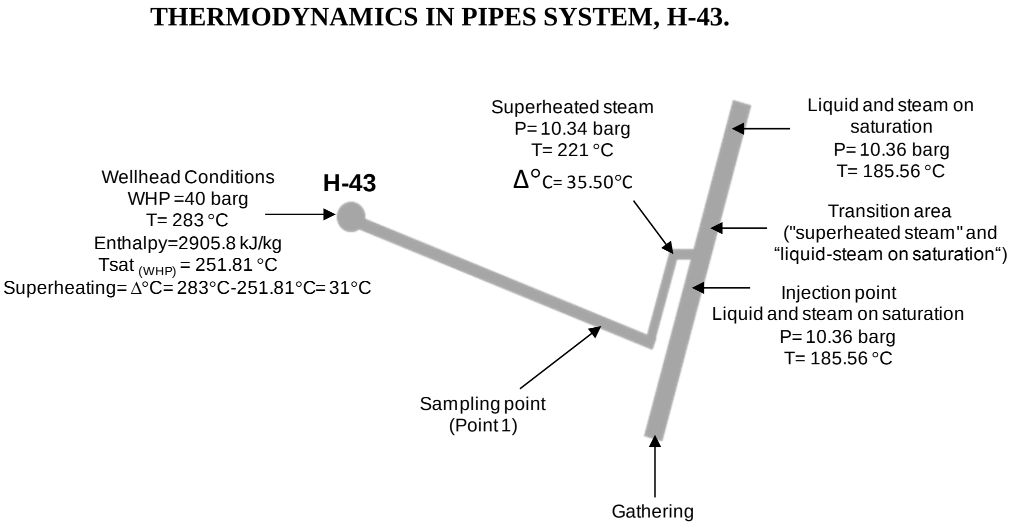

Figure 5: Thermodynamics in the gathering systems, well H-43.

3.3 Dosage of inhibitor (AMINE)

A series of representative samples of condensate fluid from H-43 were taken and analyzed under well operating condition in order to determine the dosage of corrosion inhibitor (AMINE). The chloride concentration in the steam was calculated at around 23 parts per million (ppm) and targeted to be neutralized with an injection of 35 liters/hour of solution with inhibitor at 10%. During an inhibition test, the injection point was installed in a pipe zone with more than 20 °C of superheat, resulting in scales (again observed) in the form of potassium chloride. For this reason a decision was made to inject the inhibitor into the main steam gathering pipeline, to eliminate the scaling problem (See Figure 5).

3.4 Neutralization operation on surface

The inhibitor injection point is located at 5 meters before the interconnection with well H-43 steam pipeline and in the main steam gathering pipeline. The presence of a liquid phase in the pipeline that is coming from brine and condensate from the other wells is used to prevent the formation of scale which originates by the reaction between the inhibitor and the fluid of well when this is superheated steam.

Turbulence along the pipeline and in the junction of pipes is taken advantage to promote mass transfer between the mixture (liquid and steam) and the inhibitor, which as a result has the HCl neutralization from the well.

3.5 Parameters Monitoring

Figure 6 shows the thermodynamic monitoring conducted in the well. This is performed periodically to establish if the superheat is maintained at the same level in order to assure the continued operation of the pipeline and avoid any risk to the surface facilities and gathering system up to the turbines.

Figure 7 shows the chloride monitoring conducted in the well that will allow adjustment in the dosing level if a change in chloride concentration occurs.

Figure 8 presents the iron monitoring employed to detect the presence of significant corrosion, which could be above the originally accepted and measured parameter. It can be observed that well H-43 has an acceptable behavior in iron content, which is similar to the other production wells. This result contributes to the reliability in the well's operation and stable steam supplying to the system that translates to the reliable operation of the power plant.

Although other parameters are measured, the above mentioned are the minimum that must be monitored. In addition, periodic and complementary monitoring activities that are carried out include: visual inspection and thickness measurement at the wellhead, valves and pipes which are in contact with the fluid, resulting in acceptable data.

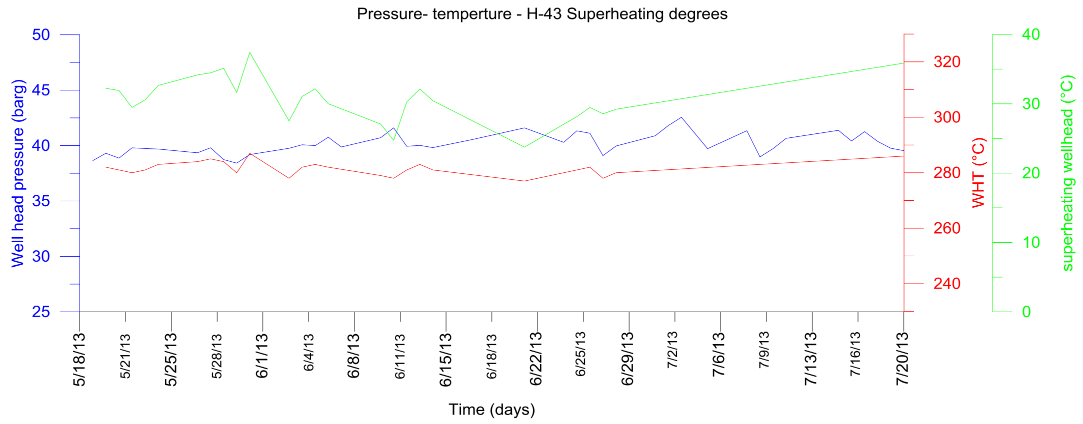

Figure 6: Thermodynamic monitoring of well H-43

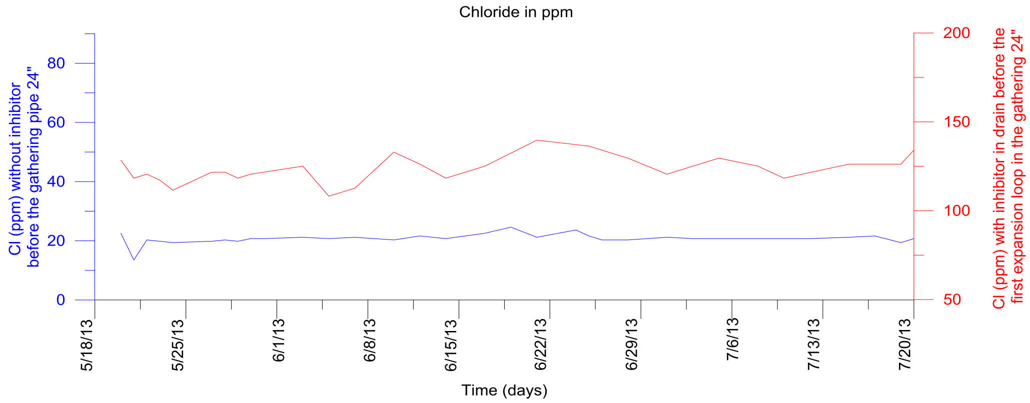

Figure 7: Chloride monitoring of well H-43.

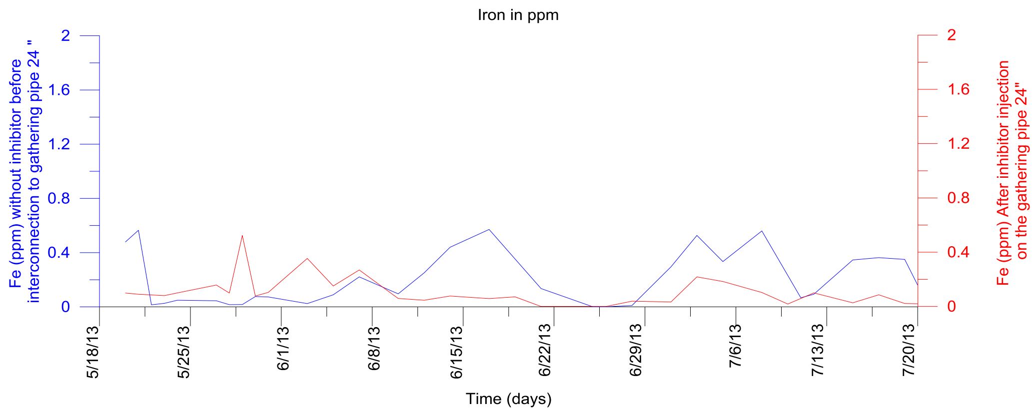

Figure 8: Iron monitoring of well H-43.

4. CONCLUSIONS

The Well H-43 has been constantly supplying steam to the plant generation system since May 2013. The well has been operating satisfactorily, taking advantage the behavior of HCl in the superheated steam and injecting a corrosion inhibitor in the gathering system, where the humidity is present. Furthermore, it is possible to improve the neutralization system in the near future, to make it more efficient.

Injection of the chemical inhibitor helps prevent corrosion in pipes and general surface equipment, allowing the use of the steam from the well H-43 to the power plant. The current production of well H-43 is around 34 tons per hour, which is equivalent to an electric generation of 4.25 MWe. The well has a high wellhead pressure, which suggests that production can still be increased, using larger diameter orifice plates.

The implementation of the neutralization system has a great impact in the future development of Los Humeros geothermal field, since it opens the possibility of exploiting wells in the deeper reservoir with similar thermodynamic and acidity characteristics, or wells with acidic fluids at saturated condition. This represents about 100 MWe of additional power generation.

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REFERENCES

Cruz, I. and Tovar, R.: Evaluación Preliminar de la Cantidad de Inhibidor de Corrosión para la Neutralización del Fluido del H-43. *CFE Files,* DINYAC-012-2008.

Diez, H.: Experiencia Operativa Neutralización H-43. *CFE Files,* DINYAC-004-2013.

Flores, A., and Tovar, A.: Fracturamiento térmico del H-40, informe interno DINYAC-006-2006. Archivo técnico de la SDE (2006).

Flores, M., Ramírez, M., Tovar, R. and Sandoval, F.: The Neutralization of Acid Fluids: An Alternative of Commercial Exploitation Wells on Los Humeros Goethermal Field. *Proceedings,* World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010.

Hirtz, P., Buck, C. and Kunznan, R: Current Techniques in Acid-Chloride Corrosion Control and Monitoring at The Geysers, *Proceedings,* Sixteenth Workshop on Geothermal Reservoir Engineering, Stanford, California, January 23-25, 1991 SGP-TR-134.

Weres, O. and Kendrick, C.: Corrosion by HCl in Dry Steam Wells Controlled using Potassium Carbonate without Destroying Superheat, *Proceedings,*GRC Transactions, Vol. 34, 2010.