Boron Removal of Steam Condensate from Los Humeros and Los Azufres Geothermal Fields in Mexico using Reverse Osmosis Process

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Keywords

Cooling Tower, concentration, boron, agriculture, drinking water, reverse osmosis (RO)

ABSTRACT

During the operation of the Los Humeros and Los Azufres geothermal fields, the "*Comisión Federal de Electricidad (CFE)*" has detected that the steam condensate from the backpressure units and the condensate excedent from the cooling towers is practically pure, except for the high boron concentration, that prohibits its use for human consumption or in agriculture applications. According to this, the CFE has decided to implement the reverse osmosis process to treat the condensate steam from the back pressure units in los Humeros, and the excedent from the cooling towers from Los Azufres, in order to reach the international quality standards. In this paper a reverse osmosis process is presented, field tests results, as well as recommendations for commercial operation.

Introduction

In the geothermal field of Los Humeros, Puebla, the CFE operates seven back pressure units of generation, part of the discharge steam, which occurs at atmospheric pressure through a silencer, is condensed (30 T/h). This condensate is practically fresh water, except for the high concentration of boron, which is over the acceptable level established by international quality standards. The CFE has determined a concentration of boron in condensate steam in the order of the 1,500.0 mg/L.

At the same time in the geothermal field of Los Azufres, Michoacán, the CFE discovered that water from the excedent of the cooling towers in the process of generation to condensation, presents similar characteristics to the condensate steam of Los Humeros. This means, that it could be considered as fresh water, except for the concentration of boron, which this time is not as high, around 15.0 mg/L.

For this reason the CFE in conjunction with the company *"Energías Alternas, Estudios y Proyectos S.A. de C.V." (ENAL)* have conducted a study to determine the viability of operating a reverse osmosis desalination plant to treat the condensate steam from the back pressure units of Los Humeros, and the excedent of the cooling towers from the condensing plants in Los Azufres, in order to obtain a product water with enough quality to reach the international standards.

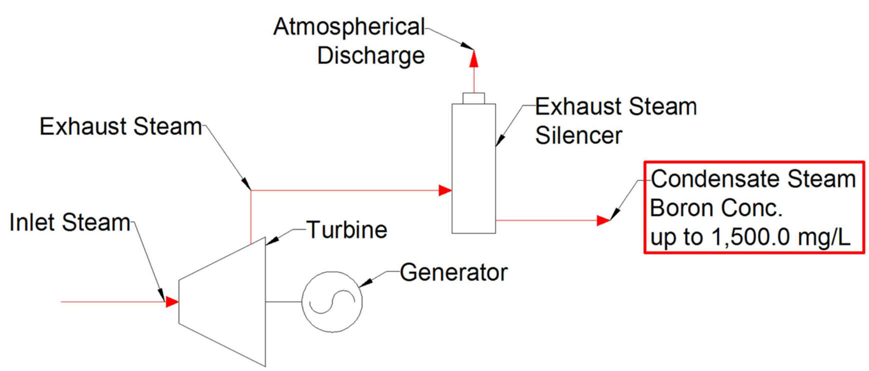

Figure 1.

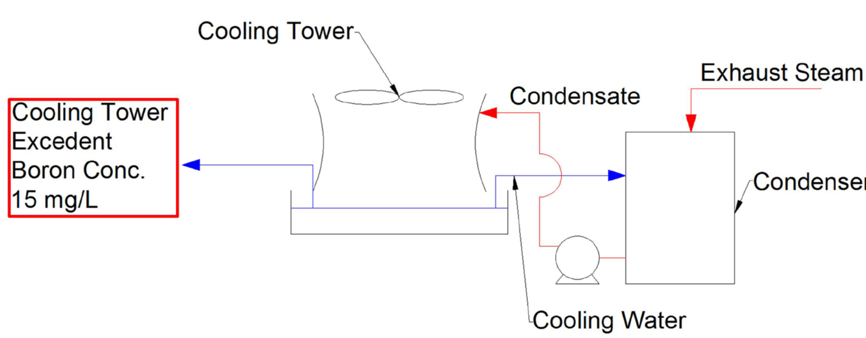

Figure 2.

The reverse osmosis process is governed by the feed pressure, salinity and temperature in the feed water, but in the case of boron removal, it also depends on the pH of the feed water. At a neutral or acid pH, the rejection of boron in the membrane is relatively low, while at basic pH, around 9.5, the boric acid change to form compounds of borate $[B(OH)_4]^-$, which is removed more effectively by the reverse osmosis membranes (WHO 2009).

Currently, some seawater reverse osmosis desalination plants in the world have a multistage array with NaOH dosage in the inlet of the second pass in order to increase the pH and consequently reduce the boron concentration in the product water. Desalination plants like Ashkelon, which treats seawater with a concentration of boron of 5 mg/L, operates under a multistage arrangement in which the first pass removes the greater amount of salts and the second pass reduces the concentration of boron up to the standards set in the region.

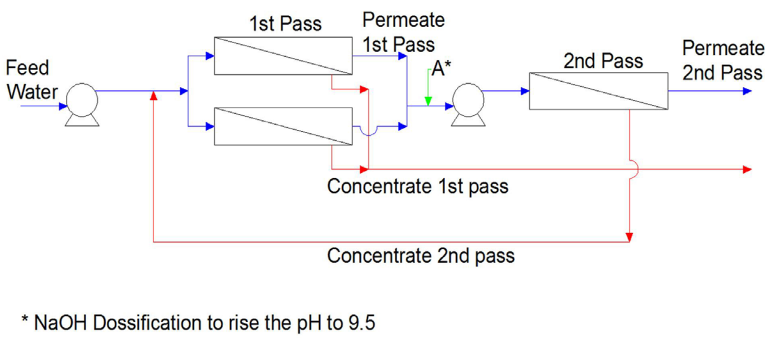

Figure 3.

Field Test

The field test was divided in two stages.

1. Field test in Los Humeros
2. Field test in Los Azufres

At both stages the criteria used to select the unit to test, was the one with the highest concentration of boron. The duration of the tests was 20 days, operating the desalination system continuously.

1st Stage

In this case, of the seven back pressure units, the unit with the highest concentration of boron presents a value of 1,757.0 mg/L. Removal of boron, to the level of concentration established by the World Health Organization (2.4 mg/L) involved an arrangement of two passes in the reverse osmosis system, dosing NaOH at the entrance of the first pass and at the entrance to the second pass to maintain a pH in the water to treat to 9.5, as well as the use of special membranes with high percentage of boron rejection.

Only by way of comparison, and in order to determine the efficiency of the membrane to remove the boron, the test ran during the first three days without addition of NaOH and with elements of membranes without high boron rejection. The concentration of boron in water product is shown in Table 1.

Table 1.

	Boron Conc. (mg/L)
Feed Water	835.9
Product Water	518.3
% Boron Rejection	38%

After this was changed the elements by elements of membranes with high boron rejection, we again, ran the test for three days without dosage of NaOH. The results are shown in Table 2.

Table 2.

	Boron Conc. (mg/L)
Feed Water	1,337.00
Product Water	144.4
% Boron Rejection	89%

The remaining days, that increases the feed pH in the water to 9.5, three samples were taken, both of feed water and product water. The results are shown in Table 3.

Table 3.

		Boron Conc. (mg/l)
1	Feed Water	1,757.00
	Producto Water	3.2
2	Feed Water	1,630.00
	Product Water	3.4
3	Feed Water	1,667.00
	Product Water	1.7
	Max. % of Boron Rejection	99.90%

At the end of the tests field, one of the elements of membranes involved in the tests was sent for analysis in order to determine any kind of scale or damage on the physical and chemical structure of the membrane. The results of the analysis were as follows:

1. The element was flushed and re-tested to evaluate salt rejection and flow rate performance. Element's NaCl rejection was recorded at 99.86%. The flux was measured at 1,054 GPD. The flux recorded was only 1% off of the original wet test performance 1,064 GPD. The salt passage recorded is actually less than what was recorded originally, by 54%.

2. Cases of indentation were found within the membrane surface.

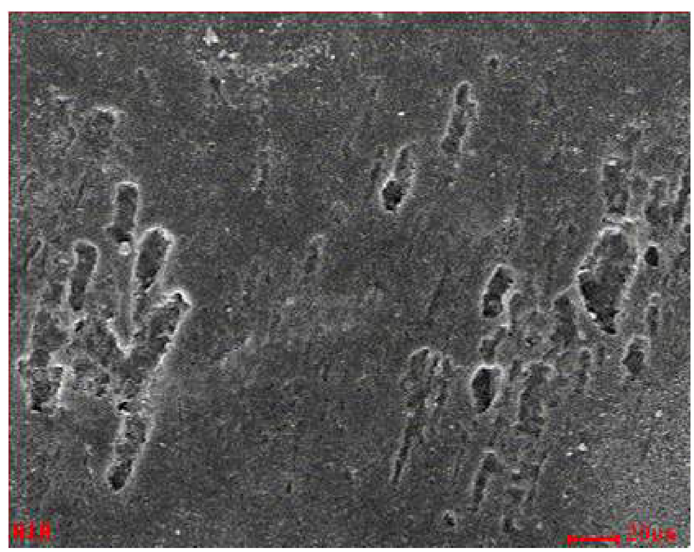

Figure 4.

3. Brown foulant comprised of silica, iron, and selenium was found. Silica was the main constituent of the foulant.

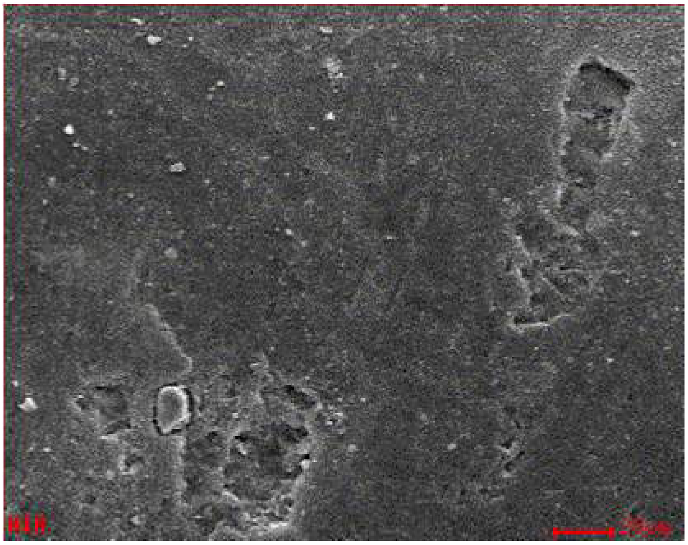

Figure 5.

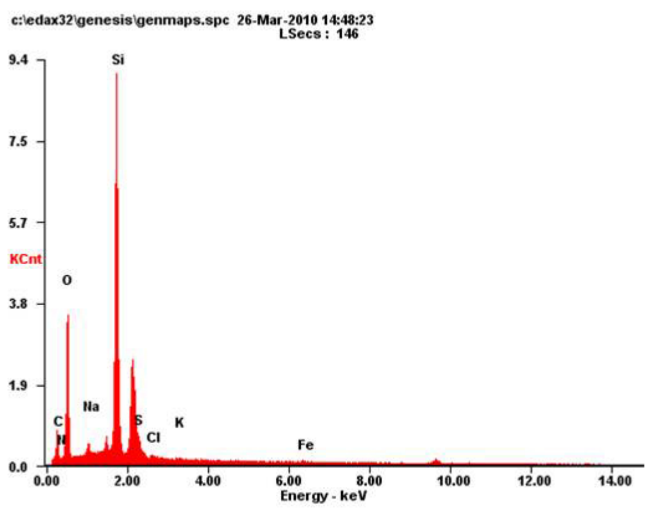

Figure 6.

2nd Stage

After testing was finished in the geothermal field of Los Humeros, testing was done on the geothermal field of Los Azufres, Michoacán. In this case only excedent was used from the cooling towers of one of the units to condensation, which at its maximum concentration presents a value of 13.7 mg/L of boron. The results showed again the effectiveness of the reverse osmosis membranes with high boron rejection, obtaining the following concentrations in the product water:

Table 4.

		Boron Conc. (mg/l)
1	Feed Water	10.1
	Producto Water	1.94
2	Feed Water	13.7
	Product Water	1
3	Feed Water	11.9
	Product Water	0.4
	Max. % of Boron Rejection	96.60%

In this case, only a single stage of desalination was needed to obtain boron concentrations below those laid down in the WHO, compared to the multistage array process used in Los Humeros.

Results Discussion

The results obtained show a great difference between the use of membranes without and with high percentage of boron rejection, from 38% to 89% of rejection of this element respectively. Better still, dosing with NaOH helped significantly, getting a boron rejection of 99.9% and a concentration of this element in the product water of only 1.7 mg/L and 0.4 mg/L in the geothermal fields of Los Humeros and Los Azufres respectively.

Conclusions

Both theory and field test have shown that the removal of boron is possible through the reverse osmosis process, provided they meet and take care of certain aspects:

- The water to treat has to be a basic pH, to change the way in which occurs the boron and can as well remove it more easily.
- The desalination system should have elements of membranes with high percentage of boron rejection. We have already seen that when installing this type of elements, the percentage of rejection of boron rose 58.3% compared to the common membranes.
- The array of the system shall be at least two pass of desalination. If you have a high concentration of boron as that found in the geothermal field of Los Humeros, then it will be necessary to increase the pH in the first and second step and thus reduce the concentration of boron to the maximum.
- One time the analysis was conducted, we will detected a light precipitation of certain salts, mainly composed of silica (SiO_2). We concluded this precipitation was caused by operating the system at a neutral pH. By increasing the pH to a basic value, we also increase the solubility of the SiO_2.

From the results obtained in the tests, it is feasible for the CFE to use a system of reverse osmosis to treat part of the water from this generation process. This treated water can be useful in their facilities and outside them, in areas where water is a limited resource. The CFE can support agricultural, social and sustainable development in the region.

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