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# Application of Solar Heating on the Electrolyte Conditioning for Electrowinning Process: Thermosolar Plant Performance

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## Abstract

In this contribution the performance of a thermosolar plant to provide heat to the copper electrowinning (EW) process is analyzed. This plant has a collecting area of 404 m<sup>2</sup> with flat plate solar collectors, and generation capacity of 540 MWh/ year. It has a thermal storage tank where water can be stored at an average temperature of 95 °C. This allows providing continuously the energy to heat the electrolyte. It was determined the performance of the solar field and global performance of the plant for a working period of 4 months at the northern region conditions from Chile. In addition, the fuel consumption reduction for replacing liquefied gas by thermal solar energy to heat the electrolyte and CO<sub>2</sub> emissions reduction were analyzed.

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## 1. Introduction

The continue increasing of the fossil fuels price and the negative effects of using them for the environment due to the gases emissions, has promoted the use of sources for renewable energy. In different regions of the world, the solar radiation is considered as one of the promising and important renewable energy sources. The northern region of Chile has one of the best potentials for solar

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applications in the world due to the fact it presents a high radiation index of 2500 kWh/m<sup>2</sup> year approximately [1].

One of the principal energetic consumer sectors is the productive. Many countries has developed technologies to replace the fossil fuels consumption for electric and thermal energy generation [2], incorporating solar energy for that purpose. For example, accordingly to IEA Solar Heating and Cooling Programme [3], several solar process heat application systems have been installed recently and commissioned in 2013, a solar cork cooking plant in Spain, a copper leaching plant in Cyprus and a retaining plant in Thailand.

In the northern region of Chile the main energy consumer is the mining industry. It is used for extraction and producing copper of high purity.

The obtaining process of copper cathode in the mining process is one of the main energy consumers, therefore one of the main fossil fuels consumers, for heating the electrolyte, to reach temperatures until 50°C approximately.

Currently the mining companies have implemented solar thermal systems for replacing the fossil fuels consumption used to heat of the electrolyte during the electrowinning process of copper. A case is the Gaby mining company that belongs to CODELCO. Other smaller mining companies have already used this technology, such as Constanza which has a thermosolar plant designed and installed by Enermine, [4] and working since November 2012. The thermosolar plant Pukará from Hatur, is the first solar plant that uses flat plane solar collectors for heating of electrolyte installed in Chile. This project is about the implementation of a thermosolar plant with a generation capacity of 90 % of the necessary energy for maintaining at 47°C the electrolyte. This is required for the electrowinning process (EW) for copper production.

In this contribution is analyzed the solar field and global plant performances respectively, during the working time period of 4 months at the conditions of the northern region in Chile. In addition, it were analyzed the fuel consumption reduction for replacing liquefied gas by thermal solar energy, to heat the electrolyte, and CO<sub>2</sub> emissions reduction.

## 2. Experimental procedure

### 2.1. Description of thermosolar plant

The thermosolar plant is constituted by a collector field of 404 m<sup>2</sup> area. The heat carrier fluid (in this case water) circulates through it. The heat is storage in a tank of 25 m<sup>3</sup> which is thermally insulated using mineral wool and polyurethane of 2.86 m diameter and 4 meters high, designed to withstand earthquakes. The heat transfer from this circuit to heat the electrolyte is through a heat exchanger. The complete process for heating the electrolyte is formed by three independents hydraulic circuits: Solar, conventional with a gas boiler and the electrolyte. The scheme of the thermosolar plant is shown in Fig 1.

The collectors of the solar field are flat plate and have a big size (2 m x 10 m approximately). The plates are oriented to the north, with a tilt angle of 30 ° respect to the horizontal plane and anchored to the field by a metallic structure made from aluminum and designed to endure the winds in the region.

Due to the nature of the solar energy, the winds and environmental conditions (room temperature, wind speed, time, etc), the temperature changes within an acceptable range. To avoid the effects of the temperature changes on the system performance, the storage tank is designed as a “flute” casts.

When the working temperature is reached in the storage tank, it exchanges or transfers heat to the second hydraulic circuit (conventional circuit with boiler and water as heat carrier) by a plate heat exchanger.

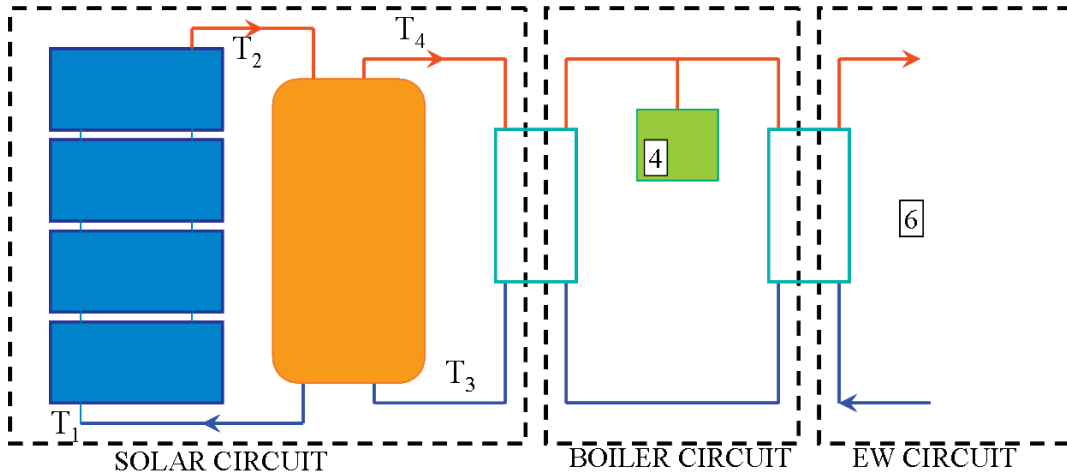


Fig1. Scheme of the Thermosolar plant: 1-solar field, 2-thermal storage tank, 3 and 5-heat exchanger, 4-boiler, 6-EW process

This circuit is connected to a gas boiler to assure reaching the temperature for the electro-winning process, in case the heat transfer from the solar system to the process is not enough to reach the required temperature.

The second hydraulic circuit transfers heat to the electrolyte which is feed to the electro-winning bank by a new heat exchanger. The thermosolar plant has a control system that regulates the flows, actuated valves and pumps and records the process temperatures.

## 2.2. Performance parameters

### 2.2.1. Performance of the thermosolar plant

The performance of the thermosolar plant ( $\eta_g$ ) is defined as the transfer energy to the electro-winning process ( $Q_e$ ) per incident solar energy ( $I_0$ ). It means the amount of collected solar energy converted to useful thermal energy for the process.

$$\eta_g = Q_e / I_0$$

where  $Q_e = m C_p (T_4 - T_3)$ , ( $m$ ) is the flow mass of water from the storage tank to the heat exchanger before it, ( $C_p$ ) is the fluid heat capacity, in this case water,  $T_4$  and  $T_3$  are the inlet and outlet temperatures to the heat exchanger ( see Fig 1).

### 2.2.2. Solar field performance

The solar field performance ( $\eta_s$ ) is defined as the relation between the incident solar energy onto the solar field ( $I_0$ ) and the thermal energy produced in the same field ( $Q_t$ ):

$$\eta_s = Q_t / I_0$$

where  $Q_f = mC_p(T_2 - T_1)$ , ( $m$ ) is the flow mass of water from the storage tank to the heat exchanger before it, ( $C_p$ ) is the fluid heat capacity, in this case water,  $T_2$  y  $T_1$  are the inlet and outlet temperatures to the heat exchanger ( see Fig 1).

### 3. Results and discussion

#### 3.1. Thermal energy performance of the plant

The monitoring system records and stores temperature, tilt radiation on the plate of the collectors and the volumetric flow rate of the plant every 10 min during the 24 h of the day.

The following analysis is based on the information from February, from 28 to 28, March, April, from 1 to 18 and May, from 1 to 15. It was not possible use the complete information from February to May due to some of the variables was not recorded by sensor failures.

In Fig. 2 can be observed the relation between the collected energy, produced energy by the solar field and the energy consumed by the EW process that comes from the therosolar plant. The amount of energy collected by the solar field indicates the amount of solar energy incident on the flat plate of collectors. The produced energy indicates the amount of energy that the solar field was able to convert from radiant energy to thermal energy. This ratio is seen in the fluid temperature increases that circulate through the solar field.

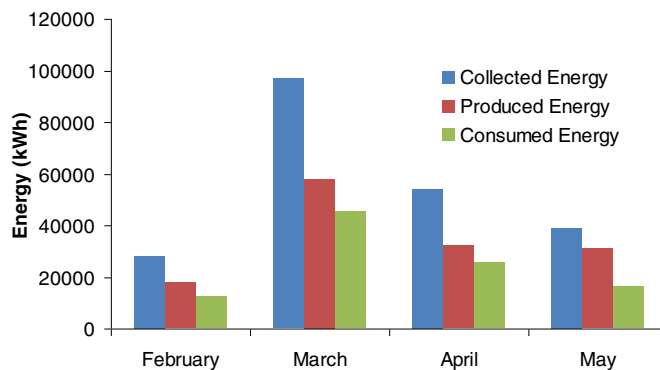


Fig 2. Energetic Balance of the plant

In Table 1 is presented the summary of the values of energy collected, produced and consumed, together with the global performance of the plant and the performance of the solar field for the working period of the plant of four months.

Table 1. Energetic Analysis for the therosolar plant and the solar field for the working period of forth months

Month	Collected Energy (KWh)	Produced Energy (KWh)	Consumed Energy (KWh)	Global Performance	Solar Field Performance
February	27993.16	17580.36	12074.36	43.1%	62.8%
March	97113.12	58190.46	45307.33	46.7%	59.9%
April	54010.76	31903.59	25589.59	47.4%	59.1%
May	38895.10	31153.85	16096.86	41.4%	80.1%

The global performance of the plant includes the percent of energy collected transferred to the electrowinning process. This value is about 42 % for May, which is the minimum value within the analyzed period time, and about the 47 % for March and April (see Table 1). The mentioned is directly related to the available energy, it means the solar radiation incident on the plant. The performance of the solar collector was about 60 % in the first month of the start up of the plant (February) and for the following months (March and April). In March the performance reached the optimum value, 80.1 %. Future work will be addressed to analyze the performance of the solar field for a longer working period for the thermosolar plant and comparing the performance for winter and summer seasons..

### 3.2. Solar field performance

The analysis to determine the relation between the incident radiation on the solar field and the variation on the inlet and outlet temperatures of water in the collectors is shown in Fig. 3. There is three consecutive days in March that presents the same behavior for the fluid temperature in the solar field. At night the temperature decreases markedly until 25 °C for  $T_1$  and 30°C for  $T_2$  approximately.

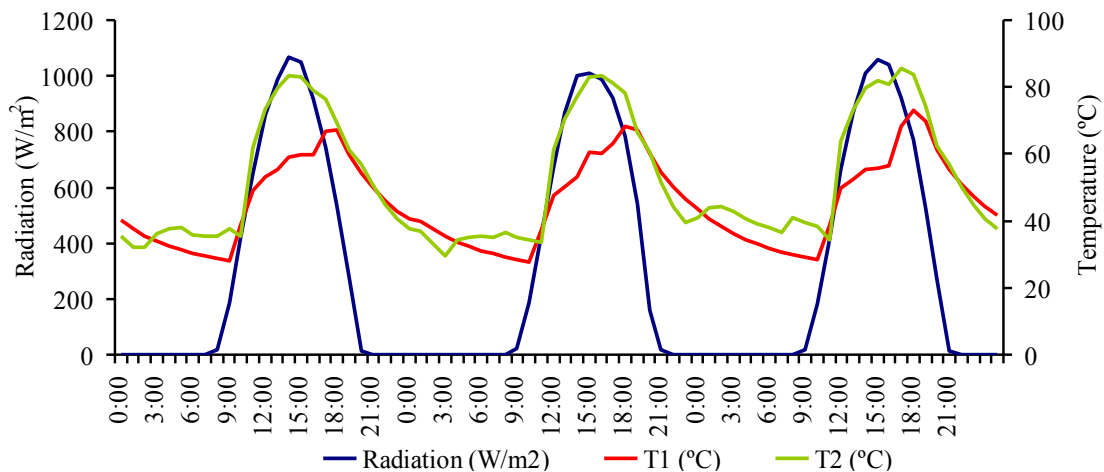


Fig. 3. Incident Radiation on the thermosolar panels and temperature variation of temperatures  $T_1$  and  $T_2$

Since the 18:00 hour approximately the solar field did not transfer energy to the storage tank and the fluid is confined inside the solar circuit only, because of its temperature level depends on the remaining energy inside the solar field. When the solar radiation is greater than 350 to 400  $W/m^2$ , the temperature increased and activated the pump for recycling the fluid between the solar field and the storage tank, then started the transfer of energy from the solar field to the storage tank, which happened around 10:00 in the morning, when the outlet temperature  $T_2$  is higher than the inlet one  $T_1$ , as shown in Fig. 3. After that, it was observed that the inlet and outlet temperatures of the field increased as consequence of the solar radiation increasing during the day. When the radiation intensity started to decrease, the solar field inertia gave to the fluid, two hours more to reach its maximum temperature, following a temperature decreasing at the outlets of the collectors. In that instant the controller of the recycling pump was activated and the feed to the storage tank from the solar field is stopped. This is restarted when the radiation intensity achieves the required value (350-400 $W/m^2$ ) in the next morning.

### 3.3. Behavior of the thermal storage tank

In Fig. 4 can be seen the relation between the available solar radiation and outlet temperature  $T_4$ , of the storage tank. This analysis is useful to obtain a relation between the storage energy and the discharge management of the plant, in addition to verify the autonomy and independence of the plant for producing heat during the 24 hours of the day.

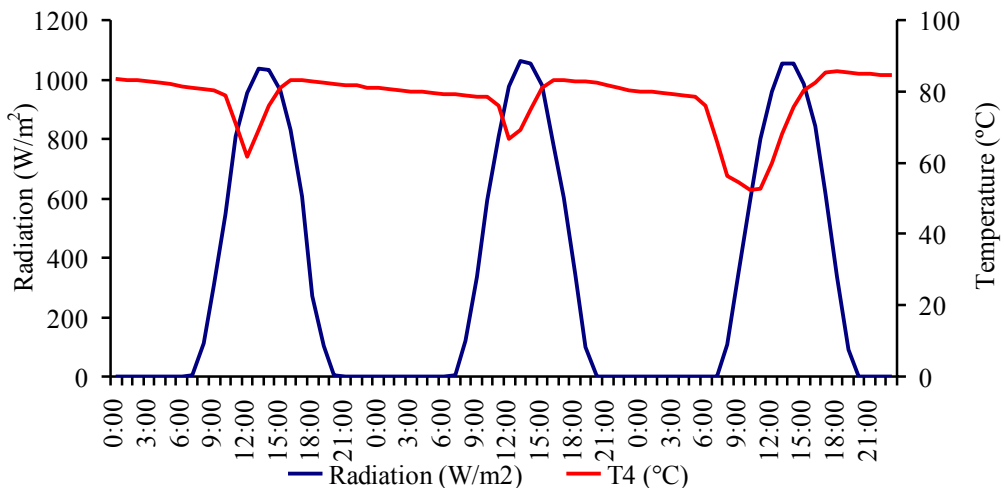


Fig. 4. Incident radiation and outlet temperature of storage plant,  $T_4$

The charge and discharge cycles for the storage tank are shown in Fig. 4. For three days of March, from 7:00 to 8:00 in the morning, the storage tank transferred almost all the energy available and the outlet temperature  $T_4$  started decreasing, the radiation is still lower than required for getting a positive energy balance and increasing the temperature. This effect was present until 10:00 or 11:00 hour in the morning, when the thermal inertia of the system was overcome and the incident solar radiation had the necessary intensity to produce enough energy to increase the outlet temperature of the tank and started a new charge cycle.

Respect to the autonomy of the plant, at low or non radiation hours, the temperature remained practically constant. It indicates the design of the equipments was appropriate, the managements and control system worked efficiently for controlling the volumetric flow rates of charge and discharge of the tank.

### 3.4. Energy saving and environmental impact

With this solar plant, the company did not require to use fossil fuel. The company was using 9,800 L/month of liquefied gas, with a density of 0.58 kg/L. Therefore they saved 68,208 kg of gas per year with the plant.

To calculate the potential  $\text{CO}_2$  emission reduction, the  $\text{CO}_2$  conversion factor for this fossil fuel in Chile is required. According to the *Ministerio de Energía* from Chile, this factor is 2,985 kg  $\text{CO}_2$ /ton liquefied gas; therefore the company has reduced the emission in 203.6 ton  $\text{CO}_2$ /year with the solar plant.

#### 4. Conclusion

The global performance of the plant is about 42 % for May, which is the lowest within the working period analyzed, and about 47 % for March and April.

The solar collectors performance is about 60% for the first month of the start-up of the plant (February) and for the following months (March and April). In March the performance reaches the optimum value of 80.1 %.

The mining company reduced the CO<sub>2</sub> emission in 203.6 ton CO<sub>2</sub>/year with the solar plant.

#### Acknowledgements

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