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Simulation of a Vacuum Cooling System for the Phosphoric Slurry: "Flash Cooler"

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Abstract

The present study concerns the phosphoric slurry cooling using a vacuum system "flash cooler". This system has a dual purpose, the first is to ensure the desired cooling of the phosphoric slurry and the second and the mainly purpose is to reduce the fluorine content in the exhaust gas outlet of the phosphate attack units. A simulation was made through the Aspen Plus software features of this vacuum system which is composed of a flash cooler to cool the slurry, a spray tower to clean the fluorinated gas and recovered it to a fluosilicic acid solution and a barometric condenser to create the vacuum all over the system. The determination of the different operating parameters of each device in order to minimize the amount of fluorine released into the atmosphere and maximizes his recovery as a solution of fluosilicic acid, were investigated. The obtained results confirmed the good performance of this system and showed that it is possible to cool the slurry to the desired phosphoric slurry temperature and get a good discount rate of fluorine released into the atmosphere. This pollutant is recovered as fluosilicic acid solution to 20% by mass.

Keywords: Fluorine removal; Flash cooler; Absorption; Fluosilicic acid; Simulation

Introduction

Emissions from the phosphoric acid process in the Chemical Tunisian Group include fluorides gaseous as hydrogen fluoride (HF) and silicon tetra fluoride (SiF_4). The gases are released during the attack on the phosphate rock. These gases, if they are released into the atmosphere unchecked, can have a negative impact on the environment. The reduction of these pollutants is in absorption towers operated under vacuum. In these towers, fluorinated gases are absorbed and recovered into a solution of fluosilicic acid at 20% by mass. This solution can be neutralized or it can serve as feedstock for the production of aluminum fluorine, hydrofluoric acid and cryolite later. Note that the temperature of gas outlet from the phosphoric unit is at 70°C, the maximum rates allowed fluoride in the effluent is determined by the Tunisian standard norm to 10 mg/Nm^3[1].

Vacuum system reducing fluorine content

The system used for cooling the phosphoric slurry and for reducing the amount of fluoride released during the phosphate attack is shown in Figure 1.

This system includes a "flash cooler" which is the mainly equipment to cool the phosphorus slurry. A pump is installed at the exit of the flash to recycle the cooled slurry in the attack tank. The steam derived from the flash cooler full of fluoride is washed in a column using a spray solution of fluosilicic acid as an absorption solution. The purpose of this column is to absorb the fluoride found as a form of HF and SiF_4 and recovered it into a fluosilicic acid solution at 20% by mass. The washed gas derived from the spray tower then passes into a barometric condenser which is responsible for creating the vacuum in all the system adopting a sea water drop.

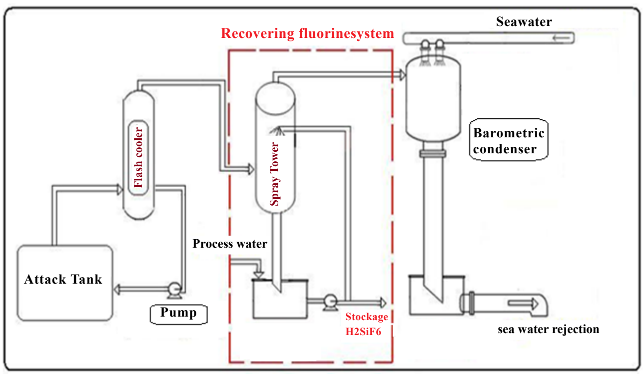

Figure 1: Flash cooler system.

Process simulation

The main objective of the process simulation is to find the optimal operating conditions:

- To maximize the recovery of fluorine,
- To ensure cooling of 3-4 degrees Celsius of the slurry at most,
- To obtain a solution of fluosilicic acid at 15-20 wt%.

To simulate this vacuum system, we used the software features over Aspen Plus. The different models of unit operations used are presented in Table 1, while interconnections between these different models are shown in the block diagram (Figure 2).

Note that the unit system used is the ''METCBAR" which expresses the temperature in °C, the pressure in bar and the mass flow in kg/h.

Operating parameters of the vacuum system

The simulation was made on the basis of an estimated composition

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of the phosphoric slurry [2,3]. The different parameters of the system to get the desired aims are listed in Table 2. The flash and the barometric condenser are assumed adiabatic.

The principles reactions considered in this system are:

$H^+ + F^- \leftrightarrow HF$ (1)

$SiO_2 + 6\,F^- + 2\,H_2O \leftrightarrow SiF_6^{--} + 4\,OH^-$ (2)

$SiO_2 + 4\,HF \leftrightarrow SiF_4 + 2\,H_2O$ (3)

Results and Interpretation

It was found that the three degrees of cooling of the phosphoric slurry is provided by a pressure of 240 mmHg at the flash. The simulation results showed that the pressure in the flash cooler has a much influence on the composition of the gas leaving it. Note that the rate of HF in the gas leaving decreases with the pressure of the flash while the rate of SiF_4 increases (Figure 3 and Figure 4). Figure 5 shows the effect of barometric condenser pressure on the consumption of sea water that provides a total condensation. It is clear that a greater flow of sea water is necessary to achieve a higher vacuum.

Equipments	Aspen Plus model
Flash cooler	Flash 2
Scrubber	Absorber (RADFRAC)
Mixer	Fsplit
Barometric condenser	Flash 2
Pump	Pump

Table 1: Different models of equipments used.

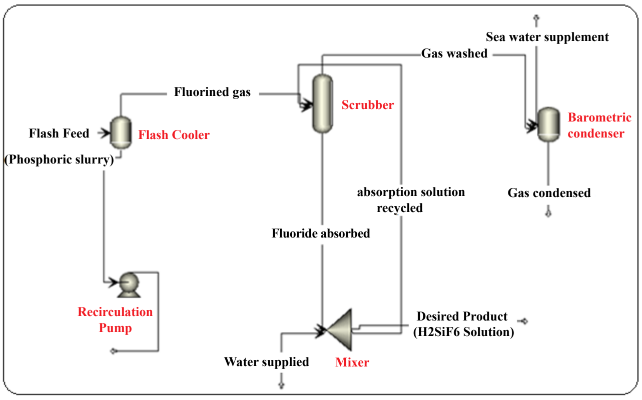

Figure 2: Block diagram of the vacuum cooling system.

Equipments	Operating parameter
Flash cooler	Pressure (bar) 0,32
Scrubber	Number of stage 10
Mixer	Rate of H_2SiF_6 (wt %) 15-20
Barometric condenser	Pressure (bar) 0,28

Table 2: Operating parameters.

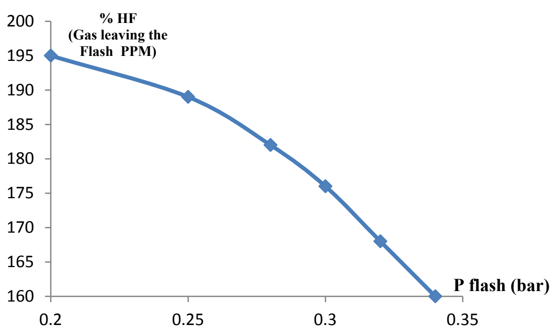

Figure 3: Pressure influence on HF rate in the fluorinated gas.

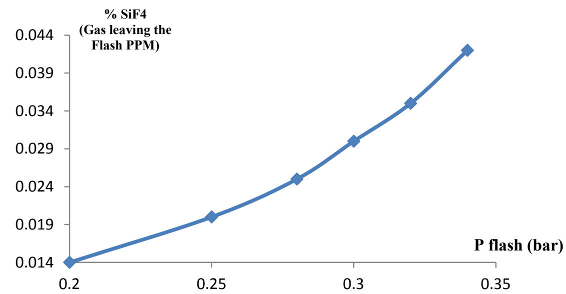

Figure 4: Pressure influence on SiF_4 rate in the fluorinated gas.

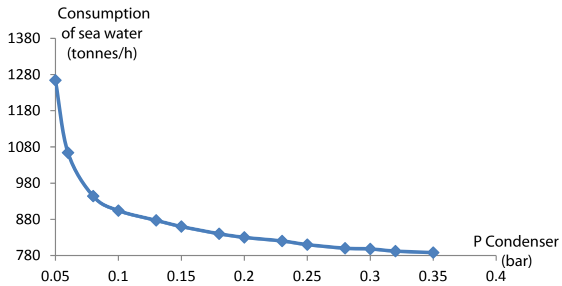

Figure 5: Pressure influence on the consumption of sea water in the barometric condenser.

	Flash Feed	Fluorinated Gas	Washed Gas	Desired Product (H_2SiF_6)	Condensed gas released at sea water
Temperature (°C)	79	76	109,5	45,3	34,2
Pressure (bar)	1	0,32	1	1,02	0,28
Flow (Tons/h)	7250	41	100,6	112	900,6
% HF	8,00E-05	168 PPM	75 PPB	traces	58 PPB
% SiF_4	0,0002	0,035	657 PPB	820 PPM	Traces
% SiF_6^{--}	0,044	0	0	20,8	Traces

Table 3: Results of the simulation.

In addition, Table 3 recapitulate the different results obtained after this simulation. We can conclude that this vacuum system has almost eliminate the fluorine rate from the gas atmospheric emission and recovered it as a fluoscilicic acid solution 20% by mass. It's clear that also the condensed gas released at the sea water contain some traces of fluorine, which confirm a good performance of this system.

Conclusion

In this work, we have elaborated a simulation of a vacuum cooling system of phosphoric slurry by the functionality of Aspen Plus features.

This system comported a flash cooler, a spray tower responsible for the absorption of fluorine, a barometric condenser for reaching the vacuum on the whole of the system. This simulation has approved that we can assure the three degrees of cooling by a pressure of 0, 32 bars in the flash and offers a good abatement of fluorine which is recovered into a fluosilicic acid solution at 20 % by mass.

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