

Processing Of Potassic Feldspar, From The West Pilbara To Potassium Fertiliser

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Abstract

The West Pilbara project situated in Western Australia focuses on the exploration and development of iron ore resources, through its exploration activities it was defined very large deposits of potassium feldspars considered rustable for extraction and production of potassium sulphate fertilisers. API Management Pty Ltd (APIM) is actively pioneering innovative processes and technologies to convert these ores into potash fertiliser, targeting an annual production of 250 kilotons pa. This effort is driven by the escalating global demand for potash fertiliser, due to the rapid growth of global population and the escalating demand for agriculturally based food production. With only one small-scale producer utilising a distinct approach for potassium sulfate production in Australia, the successful establishment of this project holds the promise of significant economic contributions to the Australian potash industry. Central to this project is the development of a pioneering salt reaction process, combining beneficiation and rotary hearth roasting (RHF) to produce potassium chloride (Muriate of Potash/MOP), further transformed into sulfate of potash (Sulfate of Potash/SOP) through interaction with SO₃. Mass and energy balances are set up for each part of the process to determine the flow rate, temperature of different material flows and estimate the amount of fuel required for the project. These data will be used to estimate CAPEX (Capital expenditure) and OPEX (operating expense) in the future and provide a reference for the commercial feasibility assessment of the project.

1. Introduction

This project focuses on using K-feldspar as a potash source simultaneously enabling potash fertiliser supply at a relatively low price and resolve the potash fertiliser supply issues in the Southern Hemisphere. Potash is a water-soluble potassium salt used to increase crop yields which is vital for plant growth, improving water retention, colour, and pest and disease resistance of food crops (Prakash & Prakash, 2016).

The raised global demand for potash fertiliser and the Russia-Ukraine war has caused a shortfall in the supply of potash fertiliser. This has led to the search for new sources of potash and the development of new technologies to exploit these unconventional sources. In Western Australia evaporated brine salts and K-feldspar are the most promising sources of potash, with Lake Mackay being the largest undeveloped SOP Salt Lake in the world. Some mining companies in Australia are trying to use solar energy to evaporate the water in these salt lakes and extract the SOP with low energy costs and reduced carbon emissions.

There have been few commercial successes in producing potash by calcination of feldspar. The main reasons are immature technology, low-value by-products and high input costs. In the early 20th century, the lack of knowledge of materials science and thermodynamics, led to the products of feldspar mostly being potassium salts, which could not be used as fertilisers, and the process was not put into commercial operation (Ciceri et al., 2015).

The APIM Pilbara project is investigating new technologies to produce SOP by calcining feldspar. The benefits of the project are to meet the demand for potash fertiliser, increase the value of by-products, reduce the cost of production and introduce new technology into the field. The process consists of four main stages: RHF, Pyrite roasting, Oxidation and SOP synthesis. After the beneficiation process, pyrite is extracted from the feldspar ore. The residual feldspar is introduced into a rotary hearth roaster, undergoing a high-temperature reaction with CaCl_2 to yield KCl . Concurrently, the isolated pyrite is directed to a roaster for calcination, resulting in the generation of SO_2 . Subsequently, these SO_2 emissions undergo drying and particulate extraction before being channelled into the oxidation process, culminating in the synthesis of SO_3 . The ultimate phase of SOP synthesis involves the interaction between SO_3 and KCl , yielding the final SOP product. Figure 1 shows a sample block diagram of the process.

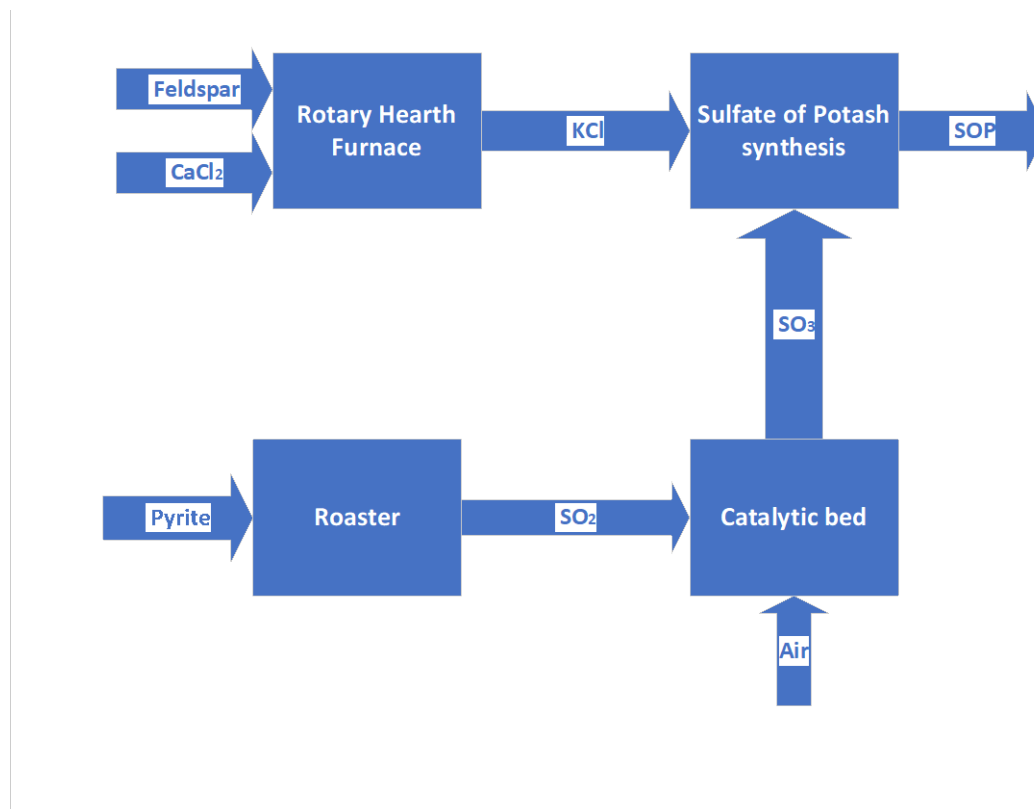


Figure 1 Block diagram of SOP synthesis process

The current study is developing the mass balance and energy balance for the new process, calculating the raw materials and fuel required to achieve the annual production of 250 kilotons potassium fertiliser. Those results will be used to determine the CAPEX and OPEX for future and provides the basis for the commercial feasibility evaluation of the project.

2. Process

2.1 Mass Balance

All feed rates have been defined to align with process requisites, inclusive of the compositional attributes of the K-feldspar and pyrite feed streams. These specifications have been ascertained through rigorous LIMN mass balancing simulations applied to the beneficiation process. The kinetics of chemical reactions are effectively elucidated through the utilisation of HSC Heat and Material Balance. In cases where empirical data is absent, the assumed occurrence of reactions with complete conversion serves as a robust foundational framework for process analysis.

2.2 Energy Balance

The heat energy of each stream is meticulously calculated using HSC's sophisticated computational tools, which consider various factors such as enthalpy, specific heat, and process conditions. The project team has determined the temperatures required by the process specification. The remainder of the required temperatures of other steps were calculated using the HSC tool based on the energy balance. To ensure accuracy, the model has included provisions for heat loss during the process. The specific heat capacity and heat generation data for all components were sourced from HSC's database.

3. Results and Discussion

The flow rate and temperature of each material flow calculated according to the mass balance and energy balance are shown in Table 1. In the calcination process of feldspar, excessive NaCl (Sodium Chloride) is required to ensure conversion. In this simulation, the ratio of feldspar/NaCl is 1:1. Separation and recovery of NaCl from the waste stream should be considered to improve the efficiency of RHF. The operating principle and some operating parameters of RHF in this simulation are from Kumar et al. (2016). Oxidation constitutes another pivotal aspect within this simulation. The oxidative transformation of SO₂ yields a substantial amount of thermal energy, judiciously harnessed for preheating the gas introduced into both the oxidation process and the SOP synthesis phase. Furthermore, the annual utilisation for SOP production entails a mere 132 kilotons of SO₃. Any surplus SO₃ shall be channelled to produce concentrated sulfuric acid, thereby serving as a marketable by-product. Operational guidelines for the pyrite roasting procedure were ascertained from the work of Runkel and Sturm (2009), while the operational parameters of the oxidation process were referenced from Davenport et al. (2006).

RHF					
Input flow	Flow rate (kt/year)	Temperature (C°)	Output flow	Flow rate (kt/year)	Temperature (C°)
<u>Feldspar</u>			<u>Solid waste</u>		
KAlSi ₃ O ₈	1000.538	25	CaAl ₂ Si ₂ O ₈	500.046	1274.106
FeS ₂	75.04	25	SiO ₂	635.71	1274.106
SiO ₂	203.728	25	FeS ₂	75.04	1274.106
C	73.64	25	CaCl ₂	801.057	1274.106
H ₂ O	117.649	25	<u>Exhaust Gas</u>		
CaCl ₂	1000.538	25	Steam	201.482	304.138
<u>Fuel</u>			CO ₂	313.607	304.138
CH ₄	21.328	25	N ₂	996.18	304.138
Air	1298.661	400	<u>KCl</u>	268	1274.106
Total	3791.122		Total	3791.122	
Pyrite roasting					
Input flow	Flow rate (kt/year)	Temperature (C°)	Output flow	Flow rate (kt/year)	Temperature (C°)
<u>Pyrite</u>			<u>Solid waste</u>		
FeS ₂	194.439	25	Fe ₂ O ₃	129.4	416.85
KAlSi ₃ O ₈	34.748	25	KAlSi ₃ O ₈	34.748	416.85
C	0.091	25	SiO ₂	0.007	416.85
SiO ₂	0.007	25	<u>SO₂</u>	207.625	416.85
H ₂ O	22.687	25	<u>Exhaust Gas</u>		
<u>Air</u>	613.33	25	Steam	22.687	416.85
			CO ₂	0.333	416.85
			N ₂	470.502	416.85
Total	865.302		Total	865.302	
Oxidation					
Input flow	Flow rate (kt/year)	Temperature (C°)	Output flow	Flow rat (kt/year)	Temperature (C°)
SO ₂	207.625	416.85	SO ₂	4.153	446.85
CO ₂	0.333	416.85	O ₂	1.037	446.85
N ₂	470.502	416.85	N ₂	641.267	446.85
<u>Air</u>	222.651	415.85	SO ₃	254.321	446.85
			CO ₂	0.333	446.85
Total	901.11		Total	901.11	
SOP synthesis					
Input flow	Flow rate (kt/year)	Temperature (C°)	Output flow	Flow rat (kt/year)	Temperature (C°)
SO ₂	4.153	446.85	SO ₂	4.153	576.556
O ₂	1.037	446.85	O ₂	1.037	576.556
N ₂	641.267	446.85	N ₂	641.267	576.556
SO ₃	254.321	446.85	SO ₃	132.009	576.556
CO ₂	0.333	446.85	HCl	111.408	576.556
KCl	227.796	446.85	CO ₂	0.333	576.556
Steam	27.53	446.85	K ₂ SO ₄	266.229	576.556
Total	1156.437			1156.437	

Table 1 Flow rate and temperature of each material stream

The Rotary Hearth Furnace (RHF) is the first time been used in feldspar roasting, as depicted in Figure 2 illustrating the energy distribution within the RHF. The roasting of 1 ton of feldspar demands an energy input of 2.6 GJ. This energy requirement comprises approximately 47.78% sourced from coal within feldspar mines, around 48.57% necessitating supplementary natural gas, and 3% recuperated via heat exchange mechanisms. It is noteworthy that energy losses are accounted for independently and are not integrated into the energy distribution. The heat loss specific to the RHF's calcination process amounts to 1.064 GJ per 1 ton of feldspar roasted.

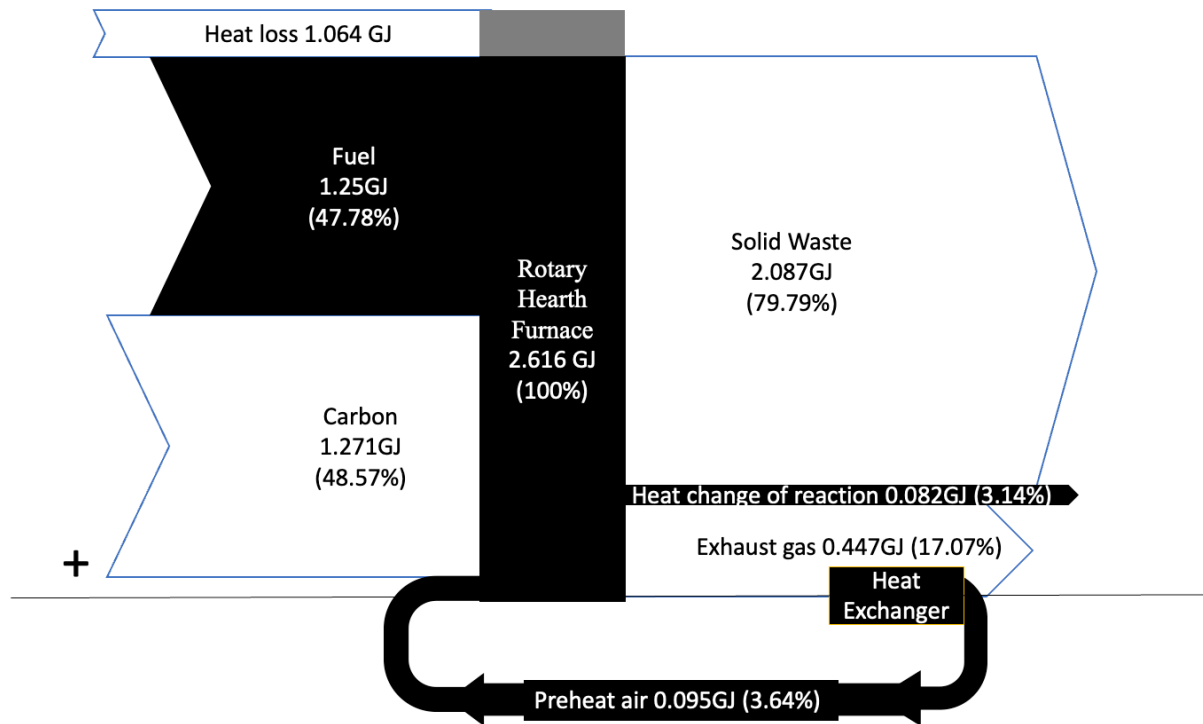


Figure 2 Energy balance and heat loss of RHF for roasting one ton of feldspar.

4. Conclusions and Future Work

This project uses HSC Heat and Material Balance to establish mass balance and energy balance for all processes in converting feldspar to SOP. The flow rate of each material flow was estimated based on the mass balance. Also, the energy requirements in the process are estimated. The required fuel requirements and the temperature of each material flow are calculated.

In future work, carbon dioxide emissions in each process should be estimated according to mass balance. High carbon emissions may lead to additional environmental costs. At the same time, estimating carbon emissions is an important step in designing carbon capture and storage systems. Another important future work is to estimate the CAPEX and OPEX of the project, to provide a basis for the commercial feasibility assessment of the project.

5. Acknowledgements

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6. References

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