NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Froth Flotation

Reference Flow: 1 kg of Rare earth concentrate

Brief Description: Mined crude ore to rare earth concentrate froth flotation process for Mountain Pass, CA

Section I: Meta Data

Geographical Coverage: United States **Region:** Mountain Pass, CA

Year Data Best Represents: 2007

Process Type: Energy Conversion (EC)

Process Scope: Gate-to-Gate Process (GG)

Allocation Applied: No

Completeness: All Relevant Flows Captured

Flows Aggregated in Data Set:

☑ Process ☑ Energy Use ☐ Energy P&D ☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☐ Greenhouse Gases	☐ Criteria Air	☐ Other
Releases to Water:	☐ Inorganic	☐ Organic Emissions	☐ Other
Water Usage:	☐ Water Consumption	☐ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

REO_crude	*[kg/kg] kg of REO-equivalent per kg crude ore*
Recovery_rate	*[%] Recovery rate for froth flotation process*
REO_product	*[kg/kg] kg REO-equivalent in product per kg of rare earth concentrate*
Wash	*0 = No; 1 = Yes*

Na2CO3_fac	[kg/kg] Sodium Carbonate/Soda Ash per kg crude ore
Weslig_fac	[kg/kg] Ammonium Lignin Sulfonate per kg crude ore

Tracked Input Flows:

Crude Ore [Intermediate]	*[Technosphere]*
Hydrochloric Acid, 10% [Intermediate]	*[Technosphere]*
Sodium Carbonate/Soda Ash [Intermediate]	*[Technosphere]*
Sodium Silicofluoride/Sodium fluosilicate [Intermediate]	*[Technosphere]*
Heat [Intermediate]	*[Technosphere]*
Ammonium Lignin Sulfonate [Intermediate]	*[Technosphere]*
Tall oil fatty acid [Intermediate]	*[Technosphere]*
Electricity [Electric power]	*[Technosphere]*
Water (unspecified) [resource]	*[Resource]*

Tracked Output Flows:

Rare earth concentrate [Intermediate product]	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DF_Stage1_O_Flotation_2014.01.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with the conversion of mined crude ore to rare earth concentrate via froth flotation. The reference flow of this unit process is: 1 kg of rare earth concentrate.

Boundary and Description

Bastnasite recovery from crude ore by froth flotation is a commonly utilized beneficiation process for rare earth concentrate production. Froth flotation physically separates particles by air bubbles that adhere to specific mineral surfaces, specifically those that are hydrophobic. This is commonly done by altering mineral surfaces via chemical treatment. Crushed and milled bastnasite crude ore, which contains gangue minerals barite, calcite, strontianite, and quartz (Gupta & Krishnamurthy 2004), are subject to several conditioning treatment steps. The slurry is heated (70-90°C) and reagents are added step-wise (Gupta & Krishnamurthy 2004). Steam, heat, and electricity requirements at Mountain Pass, CA are provided by a Molycorp Minerals, LLC onsite Combined Heat and Power (CHP) Plant (Molycorp Minerals, LLC 2010). Initially, the slurry is mixed with soda ash (Na_2CO_3), sodium fluosilicate (Na_2SiF_6), and steam. Next, the slurry is conditioned solely with steam and then ammonium lignin sulfonate is subsequently added with steam. After conditioning the pulp further with steam only, distilled tall oil is added, where it is ultimately conditioned with steam once again. The pulp is then processed via rougher flotation and then transported to a cleaner flotation process. The final concentrate from the flotation steps is ultimately thickened, filtered, and dried. This process assumes a 68% recovery rate (a minimum of 65% and a max of 70%), a rare earth oxide (REO) equivalent content of 70% in crude ore (Pradip & Fuerstenau 2013), and a REO equivalent content of 72% in the produced rare earth concentrate as shown in **Table 1**.

Figure 1: Unit Process Scope and Boundary

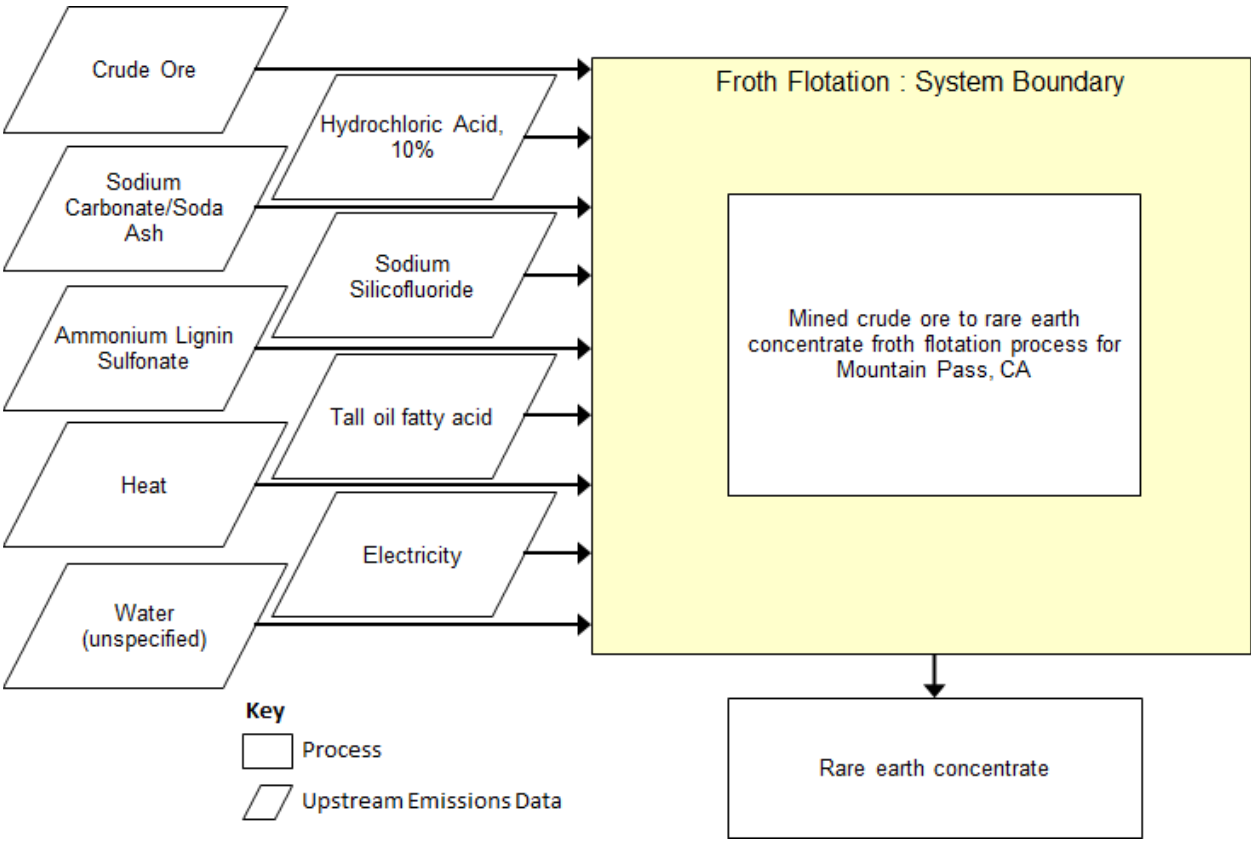

Table 1: Parameters for Calculating Crude Ore Input to Recover 1kg Rare Earth Concentrate

Parameter	Value	Max/Min	Unit	Reference
REO equivalent content in crude ore	10	NA	%	Pradip & Fuerstenau
Recovery rate	67.5	70.0/65.0	%	Pradip & Fuerstenau
REO requivalent content in rare earth concentrate product	72.0	NA	%	Pradip & Fuerstenau

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Crude Ore [Intermediate]	1.48E+01	kg
Hydrochloric Acid, 10% [Intermediate]	6.20E-01	kg
Sodium Carbonate/Soda Ash [Intermediate]	4.30E-02	kg
Sodium Silicofluoride/Sodium fluosilicate [Intermediate]	5.93E-03	kg
Heat [Intermediate]	1.22E+01	MJ
Ammonium Lignin Sulfonate [Intermediate]	4.30E-02	kg
Tall oil fatty acid [Intermediate]	4.44E-03	kg
Electricity [Electric power]	6.71-02	kWh
Water (unspecified) [resource]	4.07E+00	Kg
Outputs		
Rare earth concentrate [Intermediate product]	1.00E+00	kg

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

Gupta & Kirshnamurthy 2004 — Gupta C.K., Krishnamurthy N. (2004). Extractive Metallurgy of Rare Earths. CRC Press.

Molycorp Minerals, LLC 2010 — Molycorp Minerals, LLC (2010). Revised Mine and Reclamtion Plan for the Mountain Pass Mine. Environmental Audit, Inc. San Bernardino, CA.

Pradip & Fuerstenau 2013 — Pradip, Fuerstenau D.W. (2013). Design and development of novel flotation reagents for the beneficiation of Mountain Pass rare-earth ore. Minerals and Metallurgical Processing. Vol. 30, No. 1, pp. 1-9.

Section III: Document Control Information

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