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Dysprosium Oxide Production from Rare-earth Chloride Mixture

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Glossary

$/h	Dollars per hour
$/Mgal	Dollars per thousand gallons
$/Mlb	Dollars per thousand pounds
$/t	Dollars per metric ton
Aq	Aqueous
BFW	Boiler feedwater
bhp	Brake horsepower
BLI	Battery limits investment
°C	Degree Celsius
capex	Capital expenditure
cfm	Cubic feet per minute
¢/kWh	Cents per kilowatt-hour
¢/lb	Cents per pound
CLD	Central Lanthanide Deposit
cm	Centimeters
¢/Mgal	Cents per thousand gallons
Conc.	Concentrated
EPC	Engineering, procurement and construction
ETP	Effluent treatment plant
EV	Electric vehicle
°F	Degree Fahrenheit
FCC	Fluid catalytic cracking
FOB	Free/freight on board
FRP	Fiber-reinforced plastic
ft	Feet
G&A	General and administrative
g/L	Grams per liter
gal	Gallons
gal/lb	Gallons per pound
gpm	Gallons per minute
HEV	Hybrid electric vehicle
hp	Horsepower
$HRECl_3$	Heavy rare-earth chlorides
HREE	Heavy rare-earth element
HVAC	Heating, ventilation and air conditioning
IUPAC	International Union of Pure and Applied Chemistry
kg	Kilograms
kg/h	Kilograms per hour
kPa	Kilopascals
kW	Kilowatt
kWh	Kilowatt-hour
lb	Pounds
lb/h	Pounds per hour
lb/lb	Pounds per pound
LPS	Low-pressure steam
LREE	Light rare-earth element
µ	Micron
m	Meters
Mlb/h	Thousand pounds per hour
MMBtu/h	Million British thermal units per hour
MMlb/y	Million pounds per year
MREE	Middle rare-earth element
Mt/Mt	Thousand metric tons per thousand metric tons
N	Normality
opex	Operating expenditure

Org	Organic
OSBL	Outside battery limits
PEP	Process Economics Program
PFD	Process flow diagram
Ppt	Precipitate
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge
RE	Rare earth
$RECl_3$	Rare-earth chlorides
REE	Rare-earth element
REM	Rare-earth mineral
REO	Rare-earth oxide
$RE(OH)_3$	Rare-earth hydroxide
ROI	Return on investment
ROM	Run-of-mine
SEDT	Samarium, europium, dysprosium, and terbium
sq ft	Square feet
SS	Stainless steel
TBP	Tributyl phosphate
t/d	Metric tons per day
t/h	Metric tons per hour
t/t	Metric tons per metric ton
t/y	Metric tons per year
TFC	Total fixed capital
TREO	Total rare-earth oxide
vol.	Volume
w.r.t.	With respect to
wt%	Weight percent
y	Years

Abstract

Advancements in green technologies, and expansion of the electronics and automotive industries, are the primary driving factors promoting the significance of rare-earth minerals (REMs). The market for rare-earth elements (REE), particularly dysprosium (Dy), is expected to expand significantly as attention turns to renewable energy sources. Dysprosium is the critical constituent in the manufacturing of high-performance permanent magnets (neodymium-iron-boron [NdFeB] magnets), which are primarily critical for applications in electric vehicles (EVs), wind turbines, consumer electronics, and other high-tech products. Nearly 70%-80% of the total value of the rare-earth oxide (REO) sector is derived from the market for permanent magnets.

The production of dysprosium oxide from the heavy rare-earth chloride mixture is discussed elaborately in this review. To produce Dy_2O_3 from heavy rare-earth chloride ($HRECl_3$), the feed with a concentration of 31 grams per liter (g/L) is subjected to solvent extraction (five stages) with 2.2M PC88A in kerosene (20% saponification degree), followed by scrubbing (three stages) and stripping (three stages) steps, resulting in the individual separation of $DyCl_3$ from the $HRECl_3$ mixture. The other $HRECl_3$ (Eu, Sm, and Tb) concentrate in the raffinate. The extracted $DyCl_3$ is further precipitated using oxalic acid via precipitation, followed by calcination, to produce dysprosium oxide (Dy_2O_3). The mixed rare-earth chloride (containing Eu, Sm, and Tb) concentrate is further concentrated via evaporation, followed by crystallization, to produce mixed $RECl_3$.

This review includes an economic evaluation for an ancillary facility in a mineral processing plant, at a US Gulf Coast (USGC) location, that can produce 0.07 million pounds per year [MMlb/y] (30.76 metric tons per year [t/y]) of Dy_2O_3 from the $HRECl_3$ mixture. The technology presented here would be of great interest to industrial sectors and grassroots plants willing to produce Dy_2O_3 from $HRECl_3$ concentrate (obtained from monazite ore processing). We have estimated the capital expenditure (capex) and operating expenditure (opex) for the process to produce 0.07 MMlb/y of Dy_2O_3 from $HRECl_3$ at a USGC location, using a PEP Cost Index of 1,608 (fourth quarter of 2024).

The process flow diagrams, material balance, major equipment list with specifications, cost information for battery limits, variable costs, capex and opex, and total production costs are evaluated in this analysis. The technological and economic assessment of the process is the Process Economics Program (PEP)'s independent interpretation of a potential commercial process. Each of these is based on information presented in open literature, such as patents and technical articles, and may not reflect in whole or in part the actual plant configuration. We do believe that these sources are sufficient to represent the process and process economics within the range of accuracy necessary for the economic evaluation of a conceptual process design.

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