THE STARVED ACID LEACHING TECHNOLOGY (SALT) FOR NI/CO RECOVERY FROM LEAN ORES AND RESIDUES

International
Commodities and
Restructuring

ALTA Conference I May, 2014

Outline

- Introduction
  - Ni Laterite Developments
  - InCoR Acquires SALT
- Bench Scale Testing on SALT Process
  - Caron Plant Tailings (Brazil)
  - Saprolite Ore (Indonesia)
- SNC Lavalin Scoping Study Results
- Conclusions

INTRODUCTION

Overview
InCoR Technologies Ltd.

- Subsidiary of InCoR Holdings Pty
- Established in 2013, UK registered, listed on the First Quote of the European Regulated GXG markets with offices in London and Geneva
- Investments in Mineral Resources, Food and Agriculture and Energy
- InCoR Technologies acquired the Starved Acid Leaching Technology from Search Minerals in 2013
- InCoR Technologies is now advancing SALT toward commercialization

Introduction to Laterites

- Limonites: HPAL and Caron
- Caron – low recovery (70-85% for Ni, 20-50% for Co). Residues are potential source of Ni and Co
- Saprolites: Pyrometallurgical treatment for reduction of nickel to matte (S) or ferro nickel alloys
- The high cost pyrometallurgy requires grade of +1.8% Ni
- There are of course large amounts of saprolite that fall below this "cut-off" grade that are not currently economic.

HPAL to year 2000

- The high pressure acid leach (HPAL) process pioneered at Moa Bay in Cuba in the 1960's in the treatment of limonites.
- In the 1990's the HPAL process was touted as low cost process to revolutionize the nickel industry
- Murrin Murrin, Cawse and Bulong in Australia were started and failed economically due to high cost and slow ramp up
- At present, Cawse and Bulong are closed and Murrin Murrin continues to operate after undergoing a financial restructuring.

HPAL (Recent)

- Coral Bay Nickel – brownfields HPAL to produce mixed sulfide – technical and economic success
- Ravensthorpe – started by BHP Billiton and then sold to First Quantum for $380 MUSD.
- Goro – started construction in 2001 and still ramping up – high CAPEX
- Ambatovy – now in commercial production and ramping up – high CAPEX

Goro Nickel

- On April 25, 2001, INCO announced “INCO to Proceed with a US$1.4 Billion nickel-cobalt project at Goro, New Caledonia”.
- Years of metallurgical testwork, a $50 Million USD pilot plant in New Caledonia and detailed engineering and cost studies.
- Many stops and starts and changes over the years.
- The total capital cost of the facility has now risen to at least $6 Billion USD for a facility to produce 60,000 tonnes of nickel per annum (when it reaches operating capacity).
- Specific investment is of the order of $100,000 USD per annual tonne of Ni capacity.
- Slow ramp up
  - 4,000 t in 2012 and 16,000 t in 2013 (7% and 27% of design respectively)
- (Vale production report dated February 26, 2014).

Ambatovy Nickel

- Ambatovy nickel project (Madagascar)HPAL to process a limonite ore.
- 60,000 tpa Ni production
- Now achieved commercial production (70% of ore throughput over 30 day period)
- CAPEX - Sherritt reports on the capital costs for Ambatovy in the release of their 4th quarter results (dated April 30, 2014, www.sherritt.com).
- *"Ambatovy ceased capitalizing project costs on January 31, 2014. Cumulative spending on capital at Ambatovy was US$5.3 billion (100% basis), excluding financing charges, working capital and foreign exchange, below the US$5.5 billion (100% basis) estimate established in June 2011. Cumulative total project costs at January 31, 2014 (including operating costs, financing charges, working capital and foreign exchange, and net of sales revenue) were* ***US$7.2 billion*** *(100% basis), with US$49.9 million (100% basis) spent in January 2014."*
- **Total Capex $120,000 USD/annual tonne of Ni production**
- Significantly, Ambatovy is expected to have a period of continued "ramping" up before achieving nameplate capacity.

Nickel Opportunities?

- The economic model for HPAL treatment of greenfield nickel laterite deposits seems fatally flawed.
- At +$100,000 investment per annual tonne of nickel production, a combination of high nickel price and low operating cost are required for economic attractiveness.
- Long term nickel prices are not expected to be “high” and the operating costs for HPAL plants, while often projected to be low in engineering feasibility studies, seldom achieve this result.
- Ramp ups are often slow and uncertain.
- We need a better solution.

Nickel Opportunities?

- Caron plant tailings represent a potential source of value. At a grade of 0.4-0.5% Ni and ~0.1% Co, there is significant in-situ value in previously mined, ground, surface tailings deposits at Caron facilities.
- Economic processing of “below cut-off” grade saprolites represent an economic target for consideration. At say 1.5% Ni grade, the in-situ value of below cut-off grade saprolites is $300 USD/t using a nickel price of $20,000/t.

InCoR Approach

- Against this techno-economic backdrop we want to find a nickel laterite process that could be technically and economically successful.
- I.e. the process must be
  - Simple to engineer
  - Simple to construct
  - Simple to commission
  - Simple to ramp up
  - Simply must make a profit
- **Starved Acid Leaching Technology (SALT)** designed to use minimum acid addition in atmospheric leach to economically extract a portion of Ni+Co present

Rethinking Capital Costs

- **References from Gold and Copper Industry**
  - **Gold**: Treat ores of < 1 g/t Au (<$50/t value)
  - **Copper**: Example of Sepon Copper Project in Laos (March 2005 start)
    - Atmospheric acid leaching followed by SX-EW for cathode production.
    - Capex of $227 Million US for a production rate of 60,000 tpa of Cu.
    - $3,780/annual tonne of copper production, (1/26th of nickel HPAL)
    - Treatment rate of 170 dry tonnes per hour of ore. Capex of $152/annual tonne of ore treated.
    - The ramp up for Sepon was 2/3 of nameplate production for period April – December 2005 and then at or above nameplate from 2006 to present.
- Can we learn from these references to build cheaper plants that ramp up faster?

Sepon Copper
(Clarifier, 4 Raff CCD's, 3 Water CCD's)

InCoR Technologies Acquired SALT from Search Minerals

- Search studied Caron Plant tailings and “below cut off” grade saprolite ores
- Search signed two agreements:
  - Votorantim Metais Níquel S.A. and Votorantim Novos Negócios S.A for Caron Plant Tailings and below cutoff grade saprolites
  - PT ANTAM (Persero) Tbk ("ANTAM") for below cut off grade saprolite nickel ore from Halmahera, Pomalaa or other mining projects located within Indonesia
- Search conducted successful bench testing for these opportunities
- InCoR Technologies have now completed scoping study for application at Pomalaa with SNC Lavalin to verify financial attractiveness.

- Currently no agreement between InCoR and Votorantim or ANTAM

BENCH SCALE TESTING

TEST ATMOSPHERIC LEACHING WITH MINIMUM ACID ADDITION (SALT)

Caron Plant Tailings (Brazil)

SiO_2	Cu	Zn	Co	Ni	Cr	Mn	Al	Ca	Fe	Mg
%	ppm	ppm	ppm	ppm	ppm	ppm	%	%	%	%
29.76	1144	436	538	5072	14364	7452	3.39	0.44	30.86	3.40

100-1000 kg H_2SO_4/t, 50-80 C, 48 h of leaching

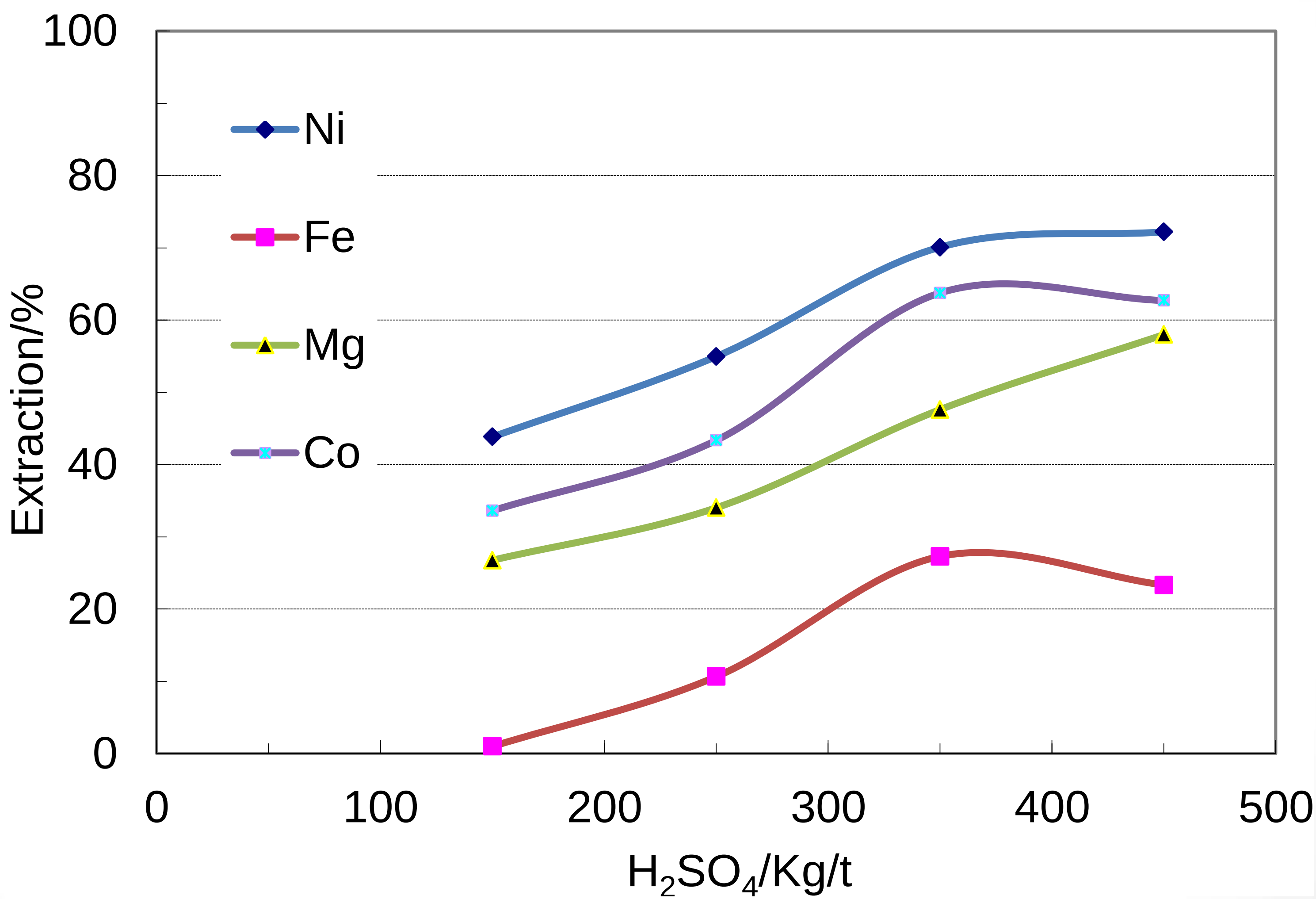
53% Ni and 70% Co extraction at 80 C and 100 kg H_2SO_4/t

INDONESIA SAPROLITE TESTING

85 °C, 8 h, 50 μm, 20% solids, aerated

Sample	Ni	Co	CO_3	SiO_2	Al	Ca	Cr	Fe	Mg	Mn
1	2.05	0.025	0.03	38.31	0.85	0.68	0.43	10.08	12.75	0.15
2	1.68	0.011	0.06	43.17	0.44	0.33	0.19	5.32	20.60	0.07
3	1.25	0.015	<0.01	43.18	0.70	0.68	0.33	7.62	17.27	0.13
4	1.04	0.015	0.10	42.12	0.47	0.57	0.24	7.60	21.01	0.13
5	1.12	0.017	<0.01	47.81	0.63	0.81	0.31	8.37	12.35	0.14
6	1.02	0.014	<0.01	42.73	0.48	0.67	0.21	7.05	19.51	0.12
7	1.35	0.023	<0.01	44.52	0.79	0.64	0.37	10.35	13.94	0.19
8	1.45	0.018	<0.01	43.27	0.51	0.44	0.27	8.81	17.59	0.15
9	0.97	0.016	0.23	42.13	0.46	0.67	0.20	7.50	19.68	0.13

Results Sample 1



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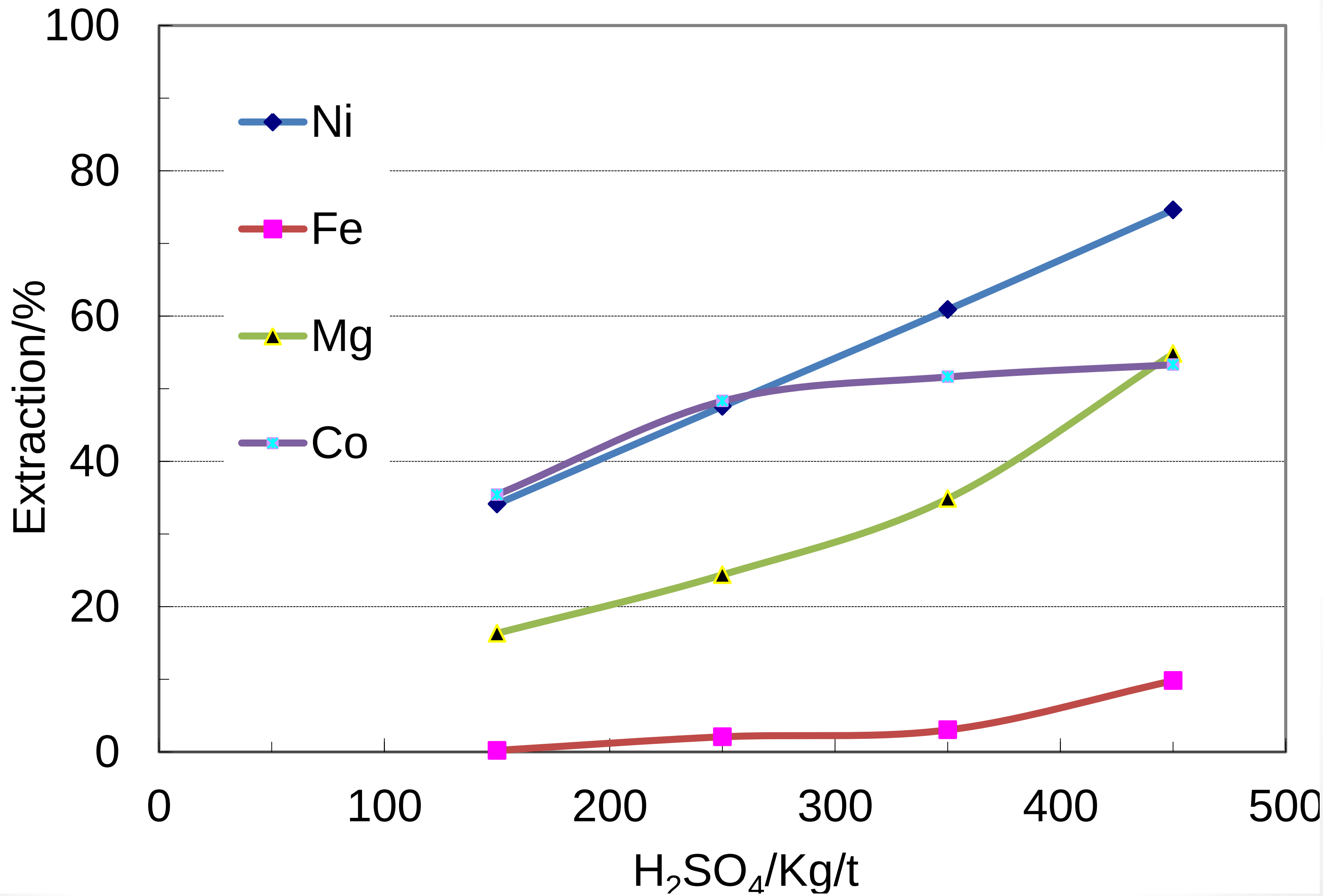

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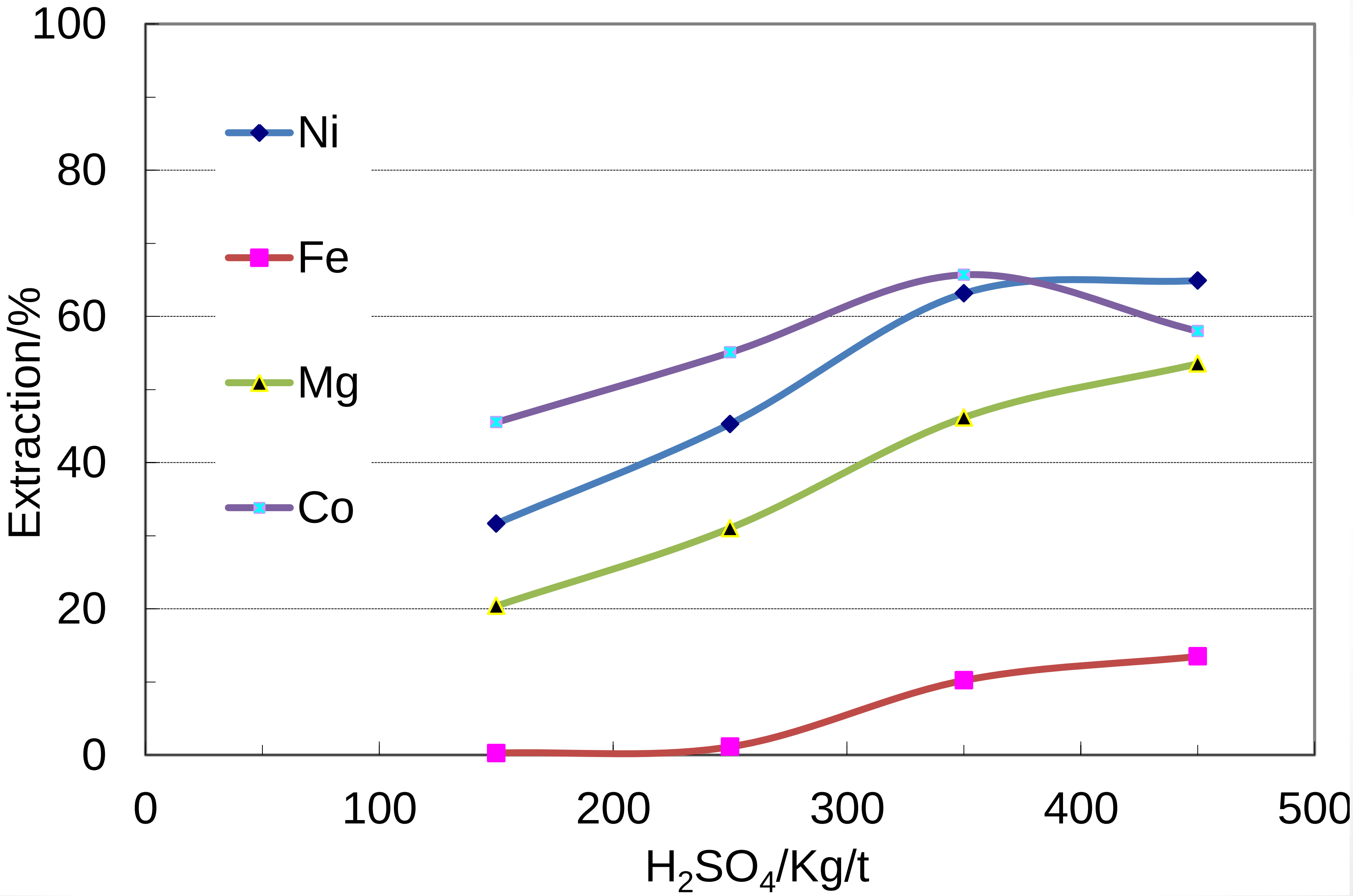

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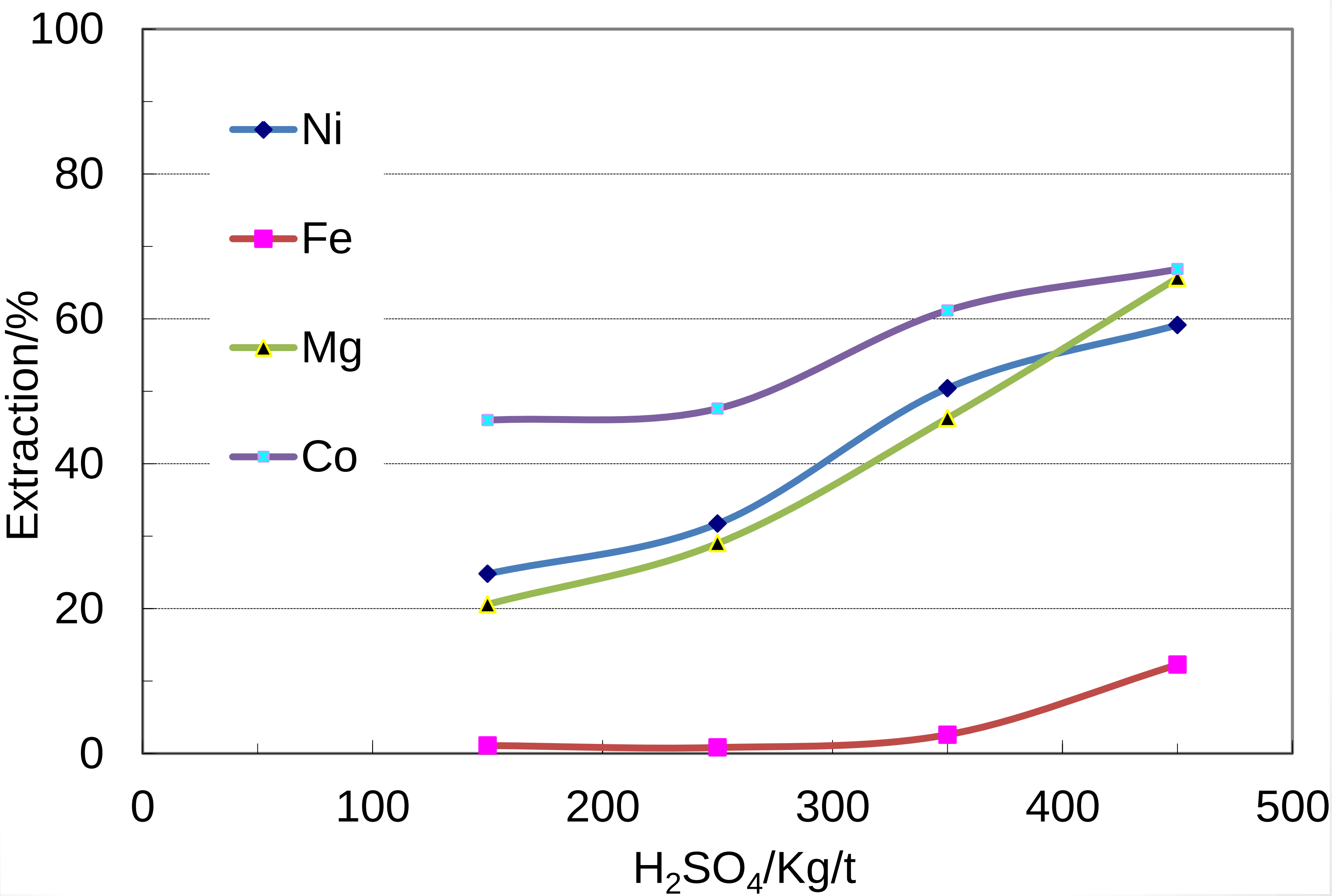

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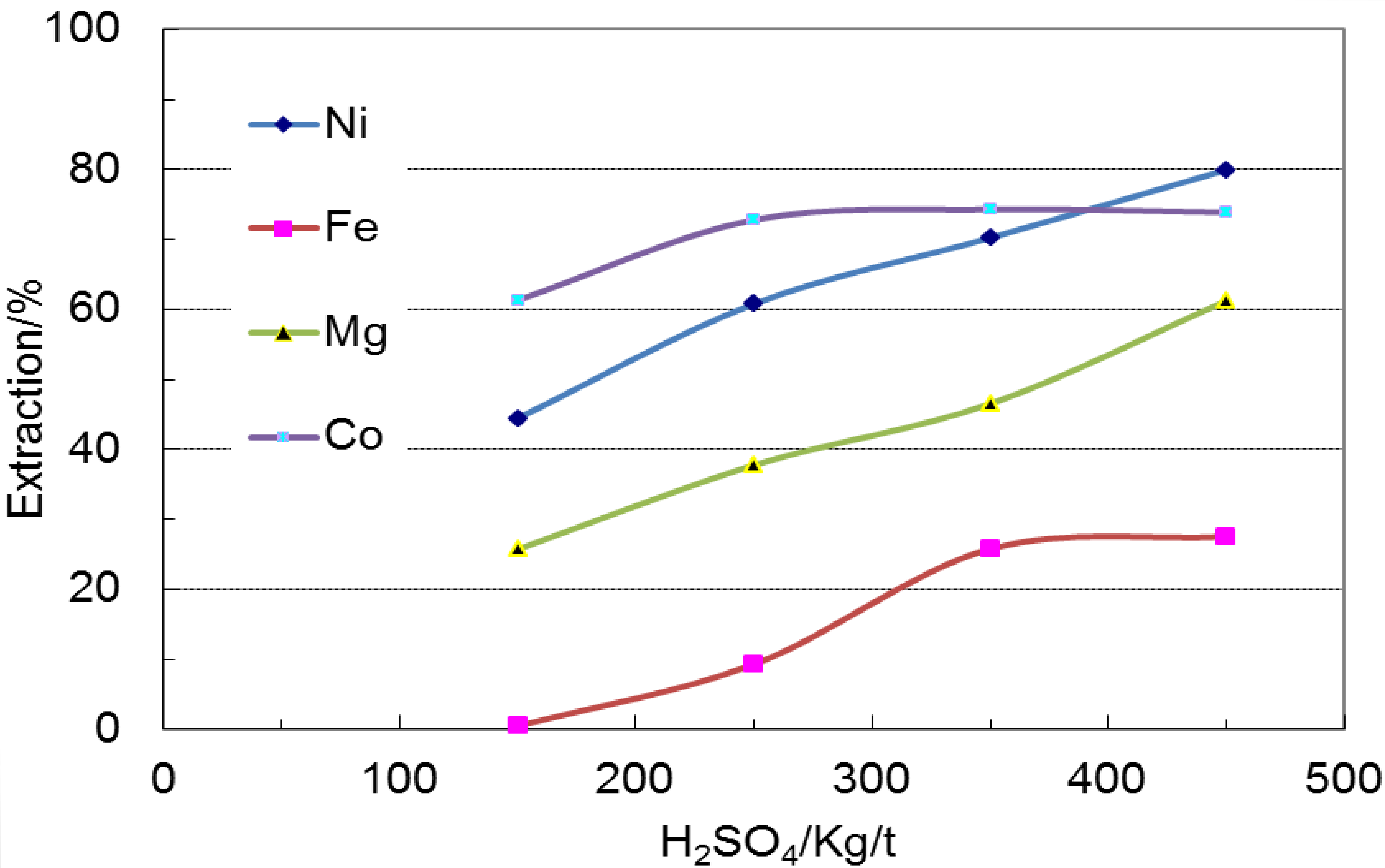

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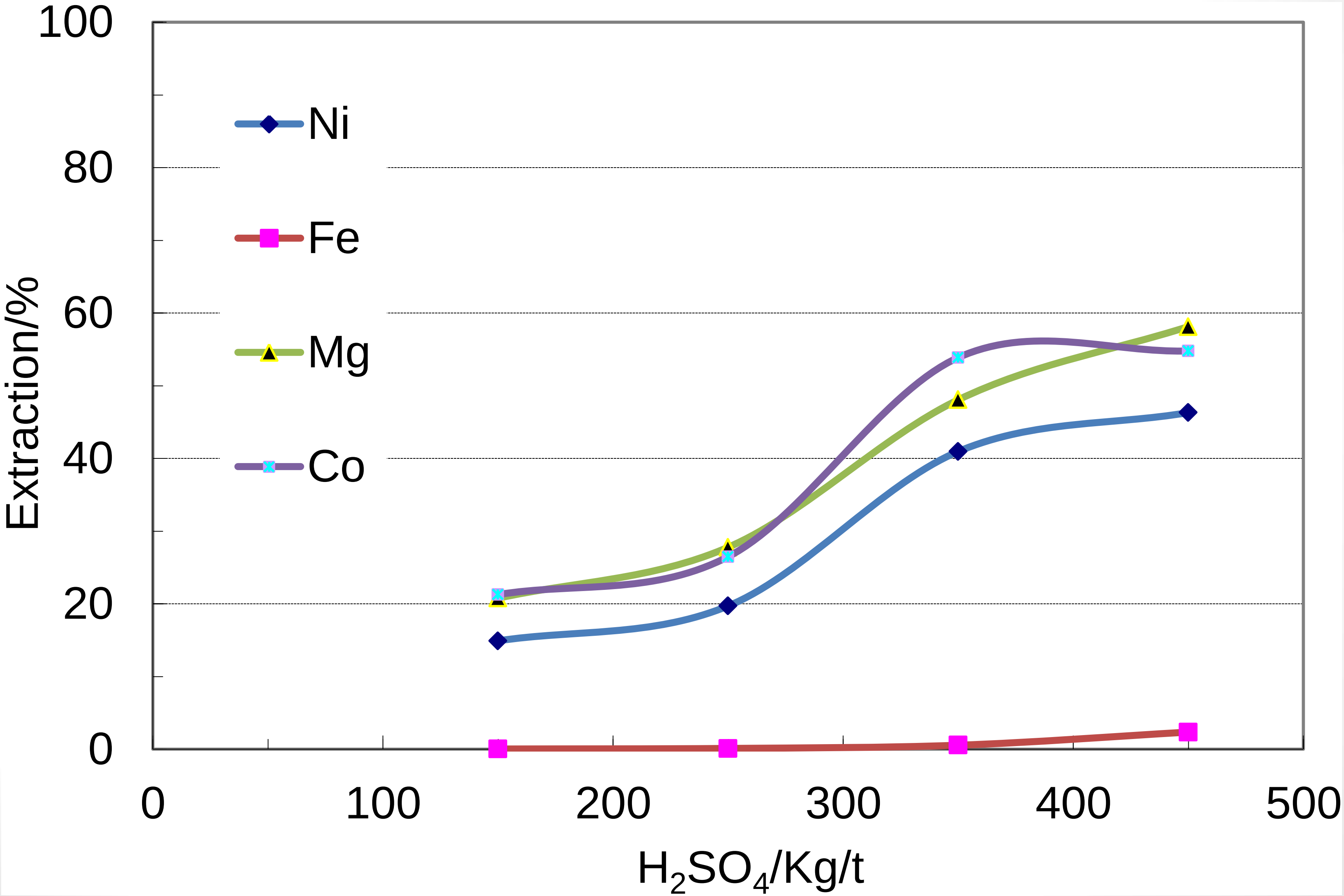

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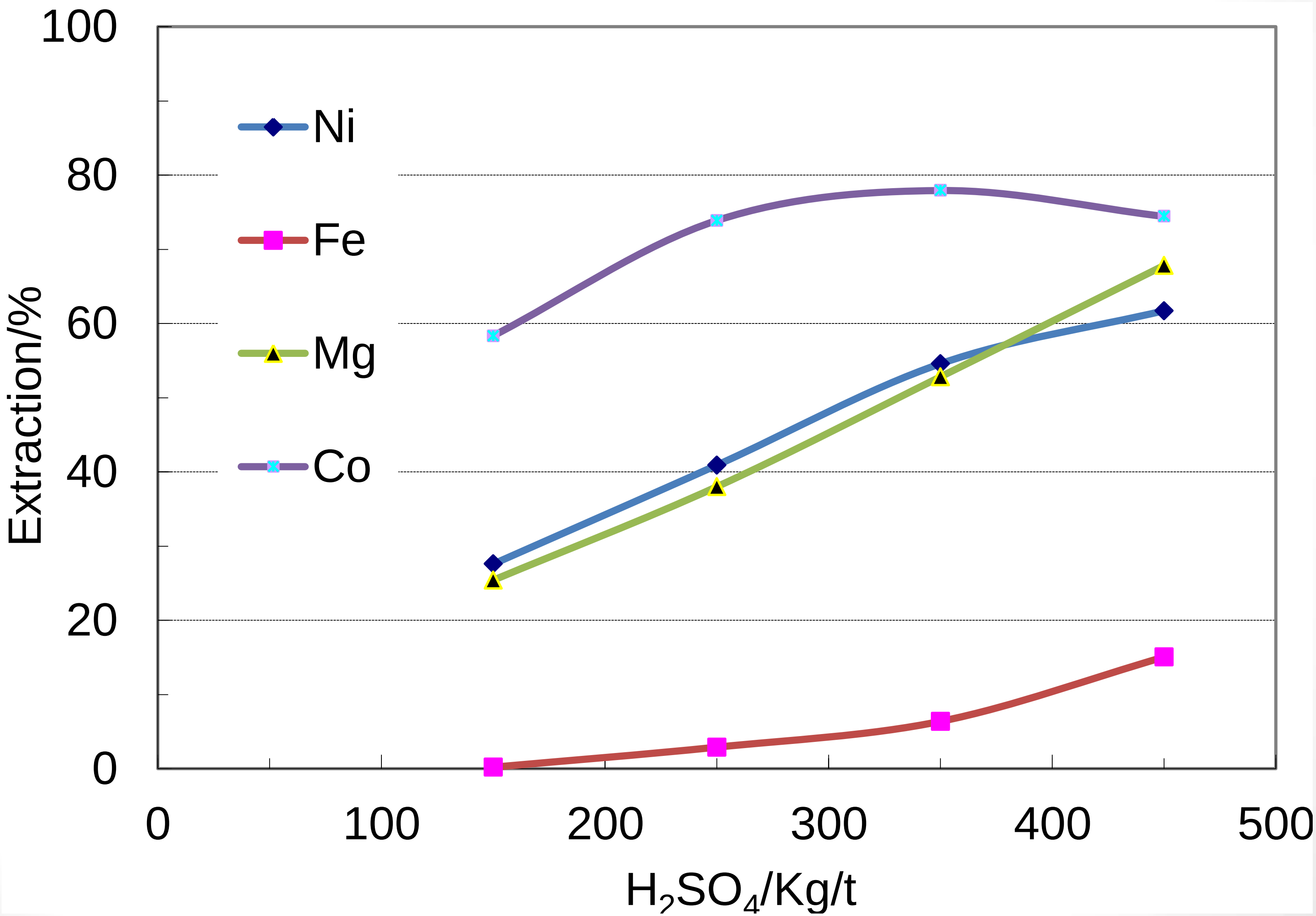

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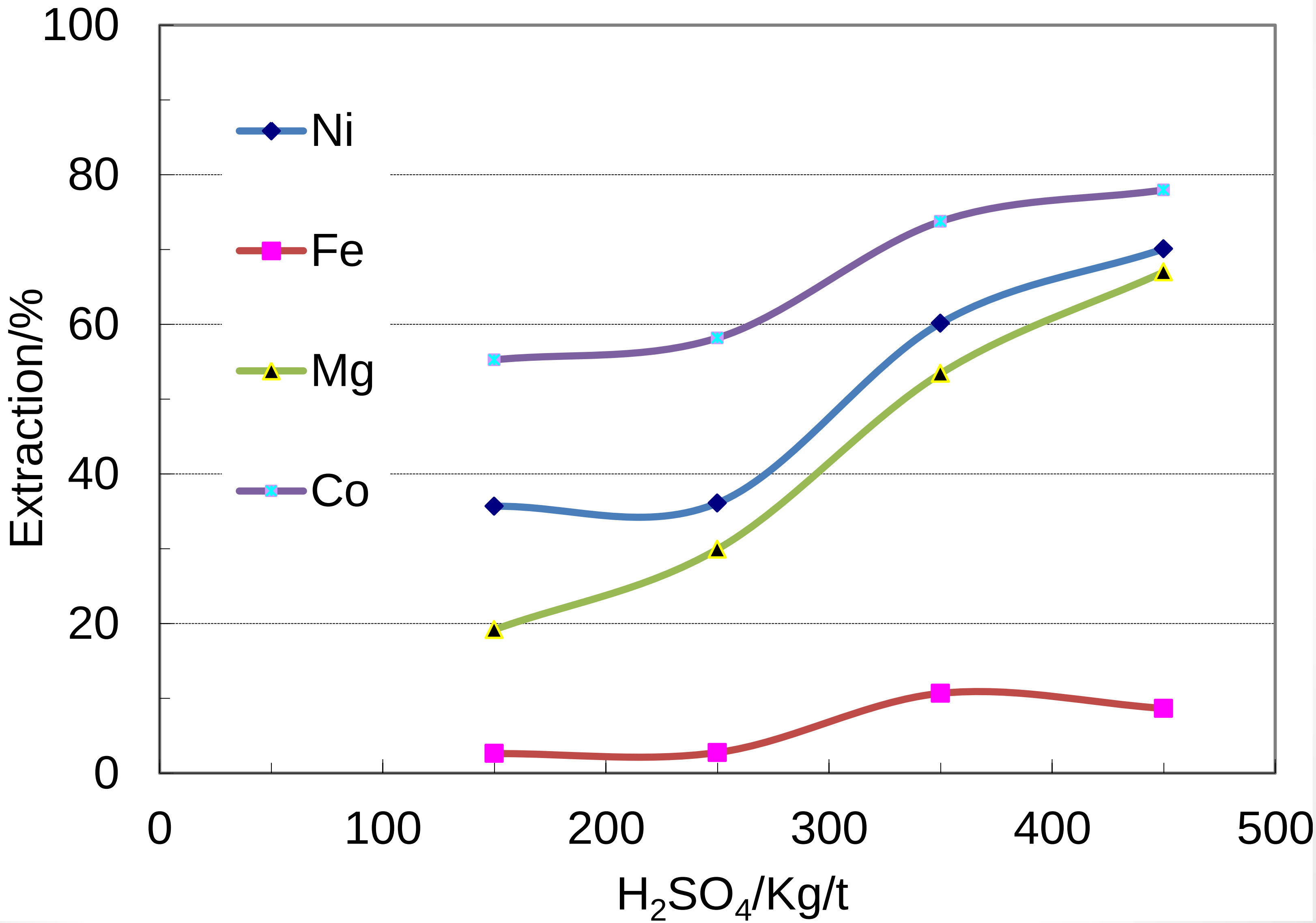
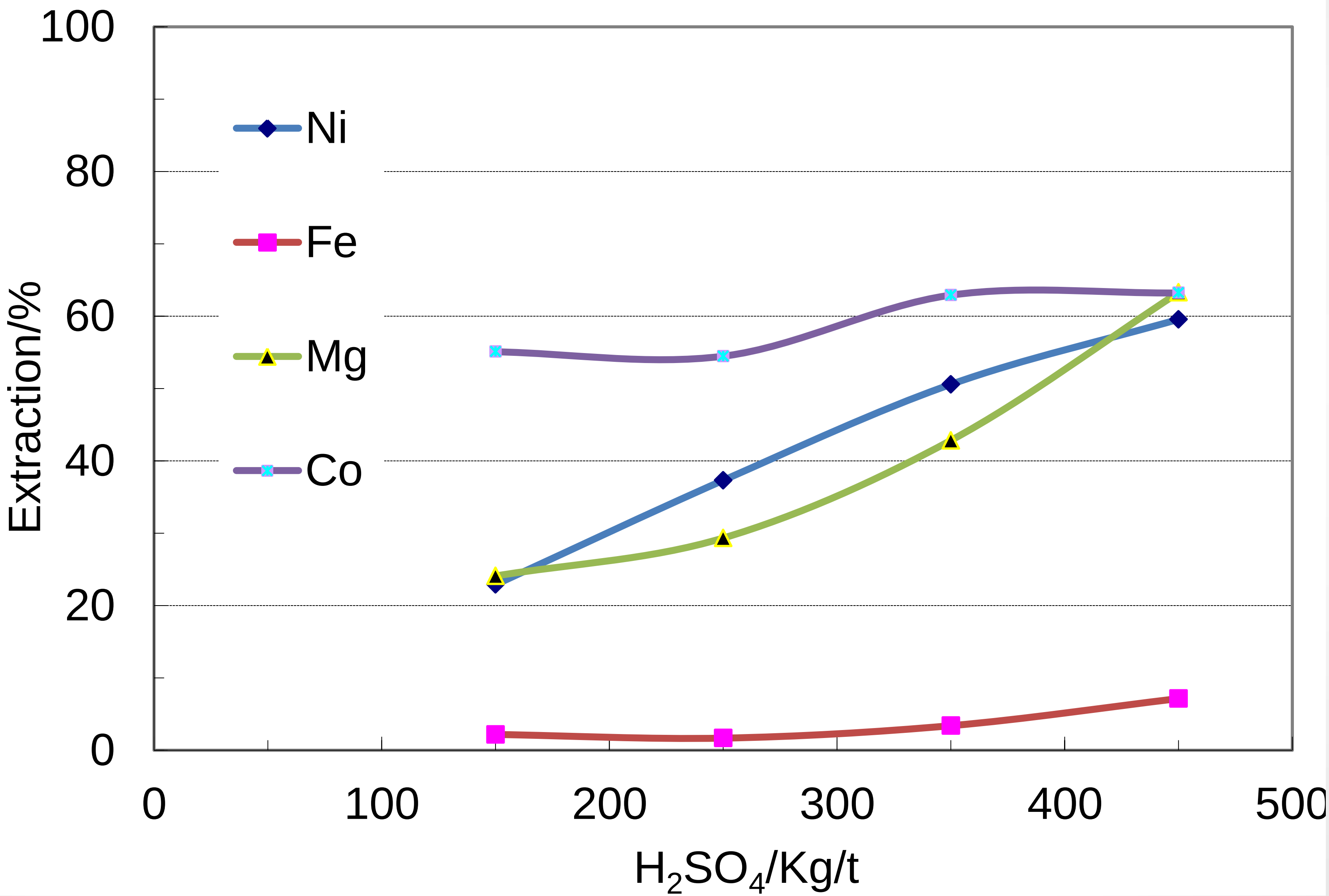
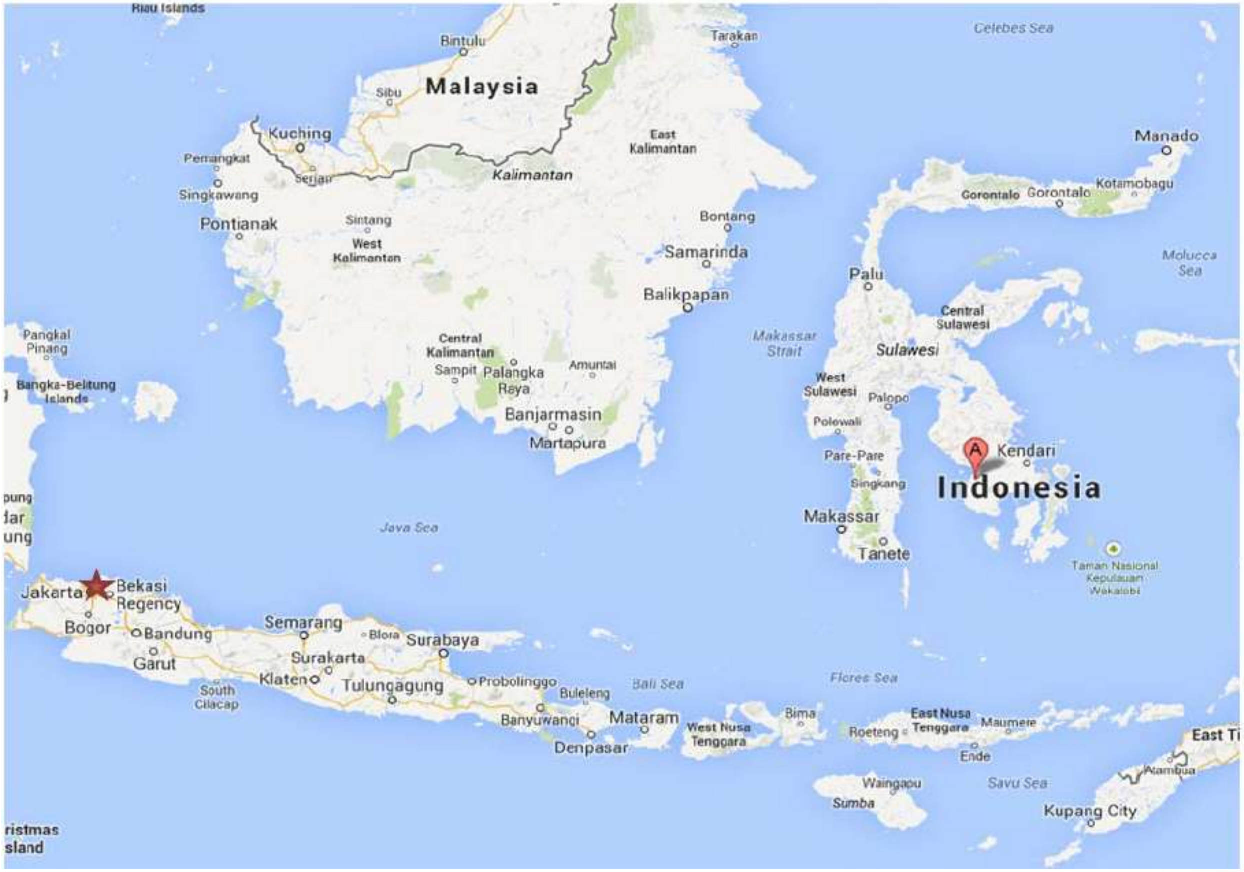


Results Sample 9



SALT FLOWSHEET DESIGN

- SNC Lavalin scoping report - application of SALT at Pomalaa.
- Site selected due to historical cooperation between PT Antam and Search Minerals.



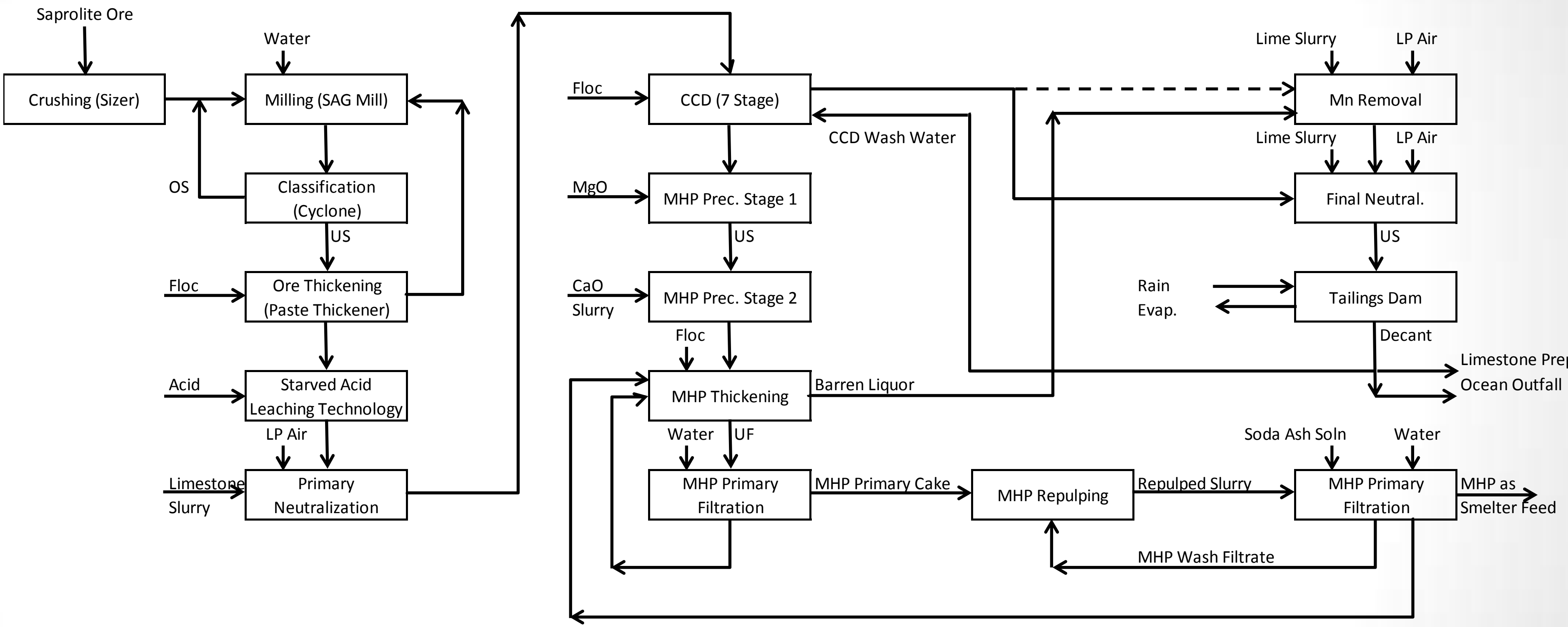
Basis (SNC Lavalin Study)

- 2 MTPA (dry) of below cut of grade saprolite ore
- The ore contains 1.33% Ni, 0.02% Co, 8.1% Fe and 17.2% Mg as an average of the samples received.
- Based on the testwork reported above
  - 350 kg/t of acid addition
  - Extractions of 57.9% (Ni), 65% (Co), 10% (Fe) and 46.5% (Mg)
  - The overall recovery to a mixed hydroxide product was predicted to be greater than 99% for Ni and Co.
  - Plant would produce 116,600 tpa of wet mixed hydroxide product containing 14,800 tpa of Ni and 214 tpa of Co.
  - Overall nickel recovery from ore to MHP of 55%.
- Assumed that the MHP would be treated in Fe-Ni Smelter

Key Flowsheet Steps

- Feed preparation
- SALT leaching
- Pre-neutralization
- CCD washing
- MHP precipitation stages 1 and 2 (with MgO and CaO respectively)
- MHP thickening, washing and filtration
- Manganese removal
- Final environmental treatment of the tailings.

Simplified Flowsheet



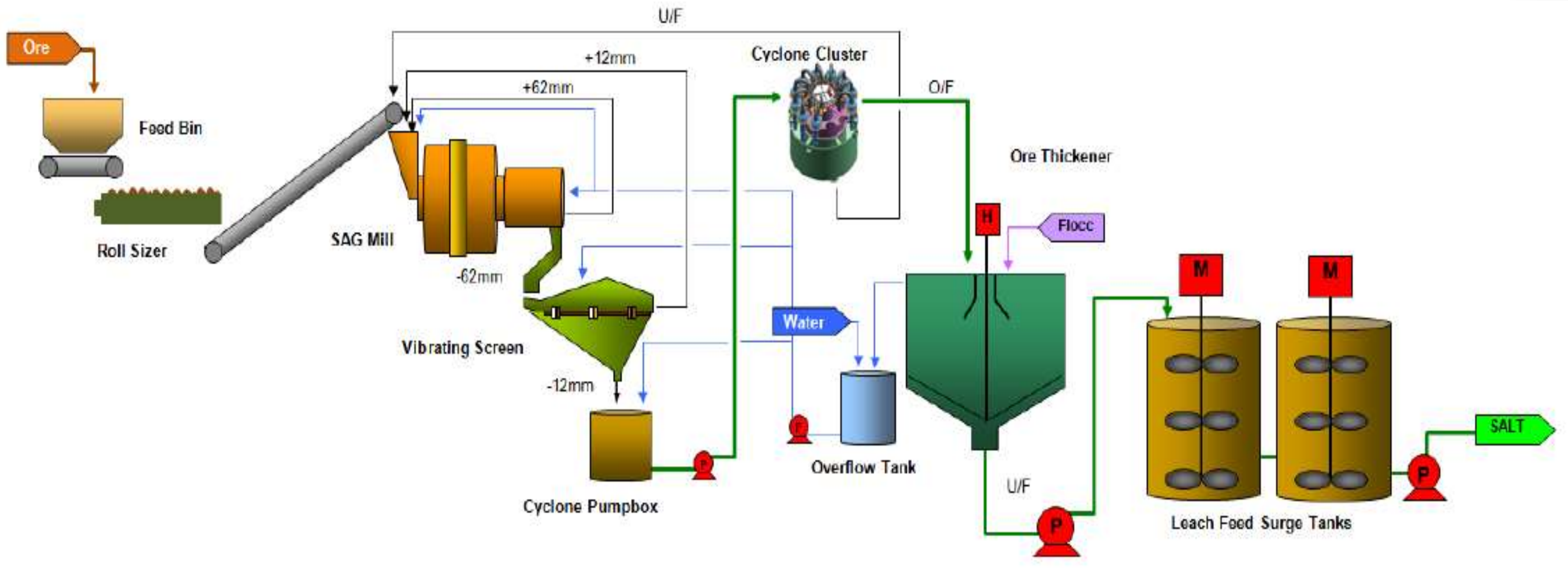
Ore Preparation

- The ore is assumed to carry 20% moisture.
- The process includes crushing of the whole ore and grinding to increase the surface area available for leaching.
- The ground ore is then classified and thickened before feeding to the SALT circuit.

Ni	Co	Al	Ca	Cr	Fe	Mg	Mn	SiO_2
1.33	0.02	0.59	0.61	0.29	8.10	17.2	0.14	42.7

- P80 of 105 µm
- Thickened to 40% solids in a deep bed paste thickener.
- 12 h of surge capacity between the ore preparation and SALT leaching circuit.

Ore Preparation Circuit



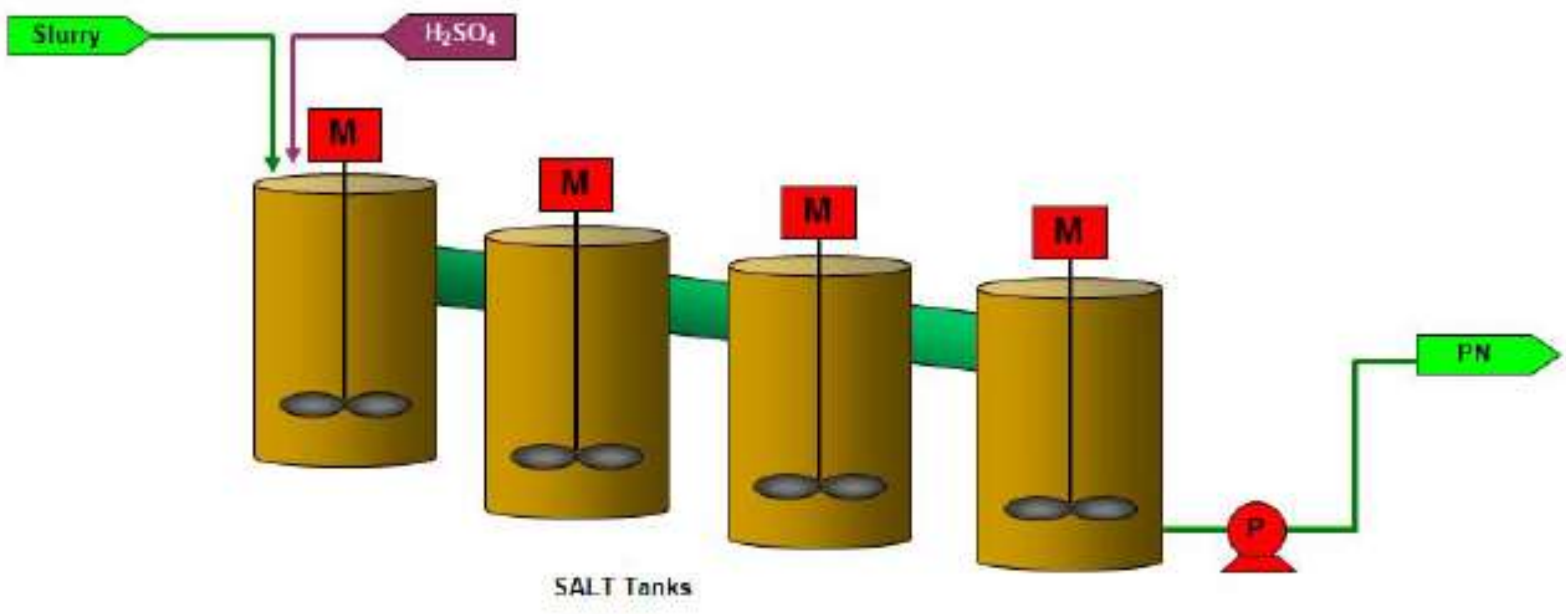
SALT Leaching Circuit

- The thickened slurry from the Leach Feed Surge Tanks is pumped to SALT circuit for leaching with concentrated sulphuric acid (98.5% w/w H_2SO_4).
- The leaching takes place in two brick-lined reactors followed by two SAF 2205 alloy reactors in series.
- A total of 8 hours retention time is allowed.
- All acid is added to the first reactor.
- Tanks are designed to maximize effective leaching and minimize short circuiting using upcomers and baffling.
- The exothermic reaction generated by the acid addition during mixing, increases the temperature of the process to about 100-105°C.
- Hence, no additional steam is required, except during start-up.

SALT Leaching Chemistry

- $NiO + H_2SO_4$ (a) = $NiSO_4$ (a) + H_2O
- $CoO + H_2SO_4$ (a) = $CoSO_4$ (a) + H_2O
- $Mg_3Si_2(OH)_4 + 3H_2SO_4$ (a) = $3MgSO_4$ (a) $+2SiO_2 + 5H_2O$
- $FeCr_2O_4 + 3H_2SO_4 = FeO + Cr_2(SO_4)_3 + 3H_2O$
- $Fe_2O_3.H_2O + 3H_2SO_4$ (a) = $Fe_2(SO_4)_3$ (a) + $4H_2O$
- $FeO + H_2SO_4$ (a) = $FeSO_4$ (a) + H_2O
- $ZnO + H_2SO_4$ (a) = $ZnSO_4$ (a) + H_2O
- $Al_2O_3.H_2O + 3H_2SO_4$ (a) = $Al_2(SO_4)_3$ (a) + $4H_2O$
- $CuO + H_2SO_4$ (a) = $CuSO_4$(a) + H_2O
- $MnO_2 + 2H_2SO_4 + FeO = MnSO_4$ (a) + $FeSO_4$ (a) + H_2O

SALT Leaching Circuit

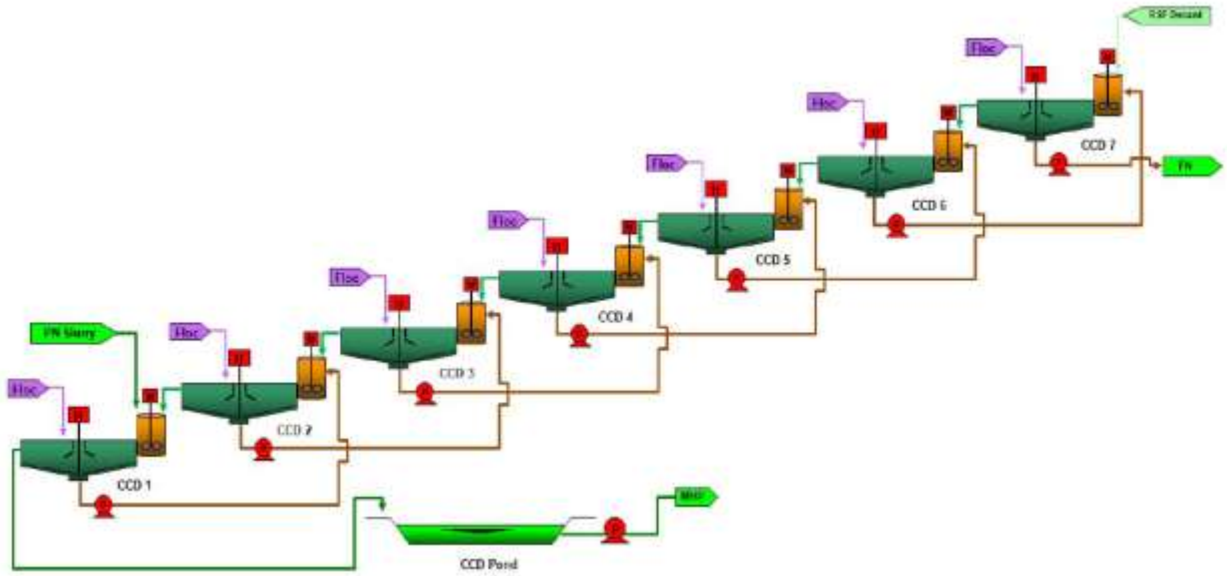


Preneutralization

- The primary neutralization circuit neutralizes the free acid and precipitates iron, aluminium and chromium with limestone addition.
- Air is injected to oxidize ferrous to ferric and enhance the removal of iron.
- <u>Removal of iron need not be complete if MHP is directed to Fe-Ni smelter</u>
- The circuit is comprised of four SAF 2205 agitated tanks, with a total reaction time of 160 minutes to ensure effective neutralisation.
- Limestone slurry is added to achieve pH 3.8 while the slurry temperature remains close to 100°C

Counter Current Decantation

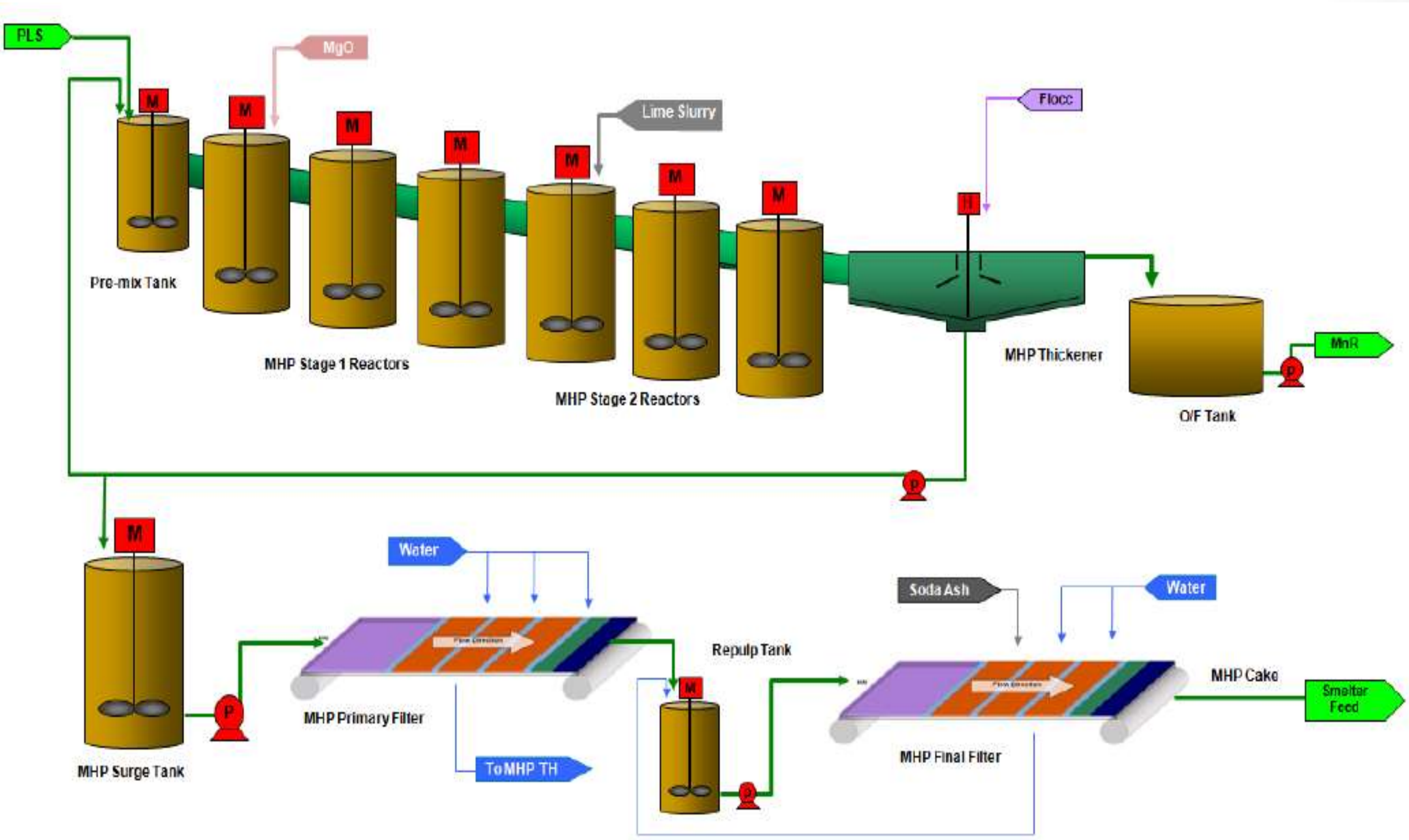
- The counter current decantation (CCD) circuit washes the leached solids and recovers a pregnant leach solution (PLS) containing nickel and cobalt values
- A 7-stage CCD circuit has been specified with 40% solids in each thickener underflow.
- The CCD 7 underflow is directed to neutralization and tailings disposal. The CCD 1 overflow is collected as the final PLS solution for mixed hydroxide recovery.



MHP Precipitation

- The PLS solution from the PLS pond is reclaimed to a series of reactors for mixed hydroxide precipitation.
- MHP Stage 1
  - MgO Precipitation
  - 60 minutes retention time
  - 91% Ni and 95% Co , precip. with Fe(II), Mn, Al, Cu, Cr and Zn
- MHP Stage 2
  - CaO Precipitation
  - 60 minutes retention time
  - +99% Ni+Co precipitation along with majority of Mn
- MHP is thickened to 20%. OF to Mn Removal Circuit
- MHP filtered repulped and filtered again with provision for soda ash washing to reduce sulfate
- Filtered MHP at 45% solids is conveyed to Fe-Ni smelter complex

MHP Precipitation Circuit



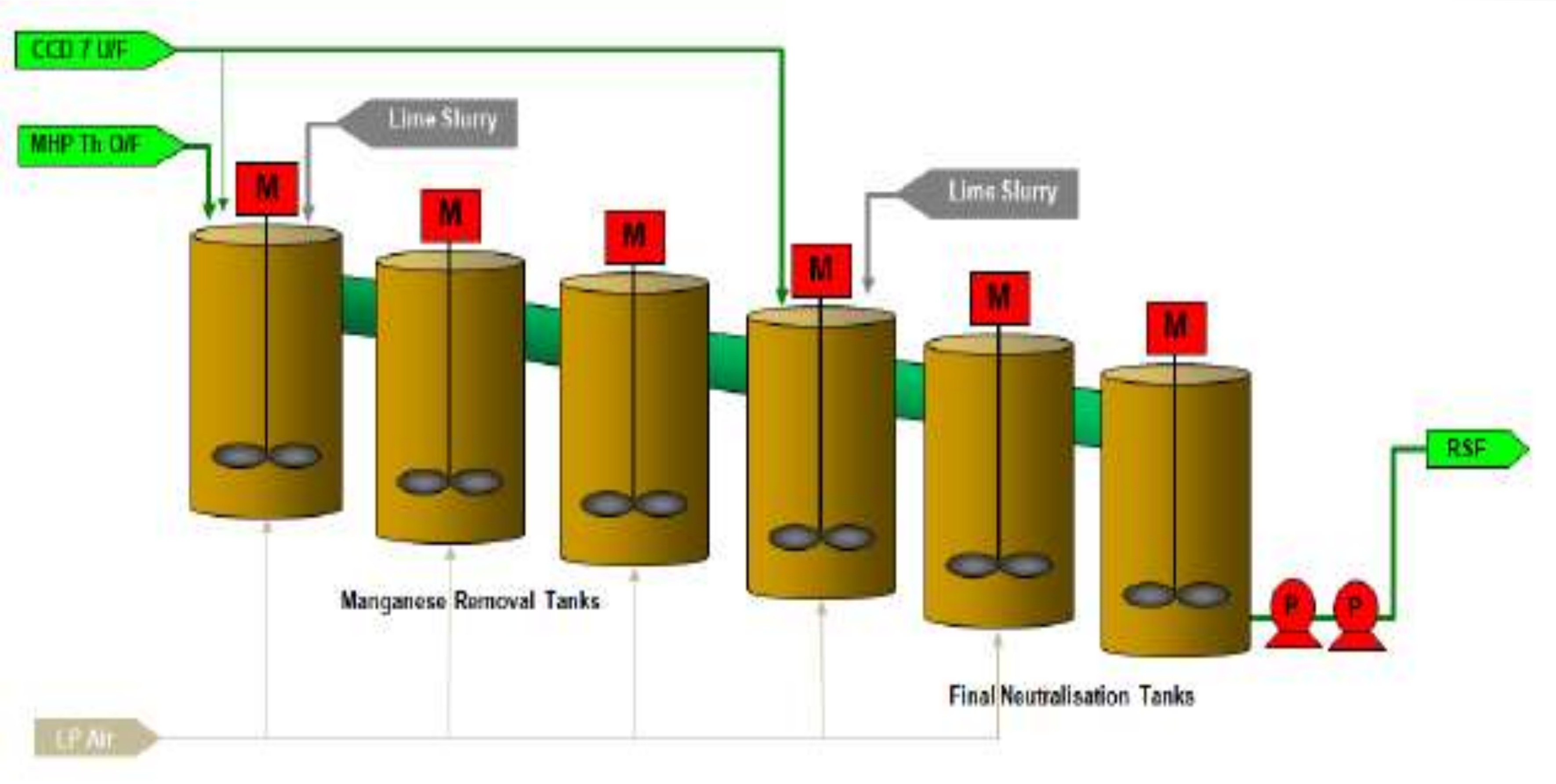
MHP Composition

Component	Composition (Wt. %)
Ni	28
Co	0.4
Mn	3.3
Mg	3.4
Fe	3.9
Al	1.7
Cr	0.2
Cu	0.1
Si	1.9
Na	0.1
Zn	0.1
S, as gypsum	3.9
S, as basic nickel sulfate	1.0
Moisture (wet % w/w)	55

Mn Removal and Final Neutralization

- MHP Thickener Overflow solution treated with lime slurry to precipitate Mn at pH 9.5-10 along with all other metals
- Reactors are aerated to form some manganese dioxide. Some CCD 7 UF slurry as seed
- Goal is < 2 mg/L Mn
- 90 minute retention time
- CCD 7 UF is treated to pH 9.5 – 10 with lime slurry
- <u>Final neutralization slurry after rainwater dilution expected to be < 1 mg/L Mn</u>

Manganese Removal and Final Neutralization Tanks



Process Plant Services and Utilities

- Sulfuric Acid: Imported by tanker. Three storage tanks provided (30 days)
- Limestone: Locally crushed limestone ground to 30% w/w solid slurry
- Lime Kiln and Slaking Plant: High consumption of CaO requires local plant. Coal fired limestone calciner with slaker (20% w/w solids)
- Magnesia: Imported fine MgO pneumatically conveyed to MHP 1
- Flocculant: Made up to 0.5% w/w stock solution
- Process Gases: Low pressure, plant and instument air
- Residue Storage Facility (RSF): Wet disposal with 2 km pipeline to tailings site. Progressively build RSF cells with time for 20 y.

Infrastructure

- Brownfield project only specific project related infrastructures are required.
- The infrastructure facilities to be provided for the project include:
  - Temporary construction facilities
  - Site works for the process plant and other facilities
  - Ship unloading facility upgrade at the port (limestone, MgO and coal)
  - Process plant and haul roads for rejects and upgrade of the existing roads
  - Utilities and services including water, power and telecommunications
  - Site and process buildings Plant loading and unloading facilities like limestone, coal and ore stockyard.
  - Mobile equipment
- The SALT process plant will take advantage of the extensive public facilities, plant facilities and infrastructure in the vicinity of Pomalaa. Existing plant facilities and infrastructure include access roads, fuel storage and refueling station, raw water pump station, communications, power plant, ore loading port and plant mobile equipment.

Power Requirements for SALT

Area	Connected Power (kW)	Used Power (kW)
Ore Preparation	6900	5100
SALT + Primary Neutralization	1000	640
CCD	1800	810
MHP Precipitation	900	470
Residue Neutralization	2100	1000
Reagent Preparation and Storage	290	140
Limestone Slurry Preparation	220	160
Lime Calcining and Slaking Plant	2300	1800
Utilities and Services	1500	900
Residue Disposal and RSF	800	350
Total	18000	11000

Infrastructure

- The current port facility at Pomalaa provides for coal and ore unloading and ferronickel product shipment.
- This facility will require upgrading for SALT for both construction and plant operations.
- The cost of port upgrading has not been included in the current capital cost estimate.

Reagent	Annual amount (tpa)
Acid	730,000
Diesel	700
Limestone, crushed	460,000
Coal	65,000
MgO	13,000
Flocculant	820
Soda Ash	1,000

Capital Cost (USD)

Area Description	Cost (US$)
Ore Preparation	20,400,000
Starved Acid Leach	5,740,000
Primary Neutralization	1,810,000
Counter Current Decantation	20,000,000
Mixed Hydroxide Precipitation	9,470,000
Manganese Removal	1,260,000
Final Neutralization	14,600,000
Residue Disposal	7,260,000
Sulphuric Acid Storage and Supply	4,890,000
MgO Distribution	302,000
Flocculant Preparation	1,890,000
Limestone Slurry Preparation	2,230,000
Lime Calcining Plant	39,470,000
Kiln Firing System	4,350,000
Lime Storage and Slaking Plant	5,890,000
Water Supply and Distribution	9,810,000
Air Supply and Distribution	4,940,000
Piperacks	1,750,000
Residue Storage Facility (Phase 1)	28,580,000
Mobile Equipment	7,510,000
Total Direct Cost	192,100,000
EPCM	48,250,000
Capital Spares	1,700,000
Commissioning Spares	280,000
Vendor Representatives	1,000,000
Contingency	38,600,000
Total Indirect Cost	89,830,000
Total Project Cost	282,000,000

February 2014 US$ basis. 1 US$ = 1.10 AUD = 11,737 IDR = 0.73 EUR.

Operating Cost

Items	Cost 1000 US$ pa			US$/lb Ni		
	Year 1	Year 2	Year 3+	Year 1	Year 2	Year 3+
Reagents/Consumables						
H_2SO_4 (98.5%)	41,200	55,800	58,800	1.80	1.79	1.80
MgO	7,200	9,770	10,300	0.31	0.31	0.31
Limestone	4,878	6,600	6,940	0.21	0.21	0.21
Sub Bit. Coal	3,400	4,610	4,850	0.15	0.15	0.15
Flocculant	1,410	1,920	2,020	0.06	0.06	0.06
Soda Ash	210	285	300	0.01	0.01	0.01
Proc. Plant Consumables	1,910	2,580	2,720	0.08	0.08	0.08
Power Consumption	7,340	8,150	8,150	0.32	0.26	0.25
Utilities/Services /Reagents/Consumables	1,360	1,290	1,300	0.06	0.04	0.04
Labour	4,240	4,240	4,240	0.19	0.14	0.13
General Expenses	5,000	5,000	5,000	0.22	0.16	0.15
Maintenance Materials	3,740	3,740	3,740	0.16	0.12	0.11
Contract Services	4,040	4,030	3,770	0.18	0.13	0.12
RSF Sustaining Capital	0	0	6,530	0	0	0.20
PROJECT OPERATING COST	86,000	108,000	119,000	3.75	3.47	3.62

Scope of Operating Cost Estimate

- The operating cost estimate for the project is based on the process mass balance (Full METSIM Balance).
- Variable Costs:
  - Reagents and consumables
  - Maintenance materials
  - Contract expenses
- Fixed Costs:
  - Labour (including administration and general expenses costs)
  - Administration and General Expenses
  - Sustaining capital cost
- Reagent cost includes shipping and freight and therefore considered site-delivered price, but ore is considered to be mined and delivered to the ROM stockpile at no charge.

Ramp Up

- The estimate is based on a steady ramp up to full operational performance.
- Year 1 – 70%
- Year 2 – 95%
- Year 3+ - 100%

Reagent Costs

- H_2SO_4 - 80 US$/t
- MgO - 788 US$/t
- Limestone – 15 US$/t
- Sub-bituminous coal – 75 US$/t
- Flocculant – 2,460 US$/t

Labour and Supervision

- A total of 36 non-western expatriates and 332 local/national workers have been allowed
- Labour has been estimated to cover the complete plant including:
  - Process plant operations;
  - Utilities and services personnel for acid loading/unloading, limestone slurry and lime calcining and slaking plants, water services, process gases and other systems
  - Maintenance personnel to provide maintenance services to all plant areas
  - Technical staff in areas such as environmental, laboratory, process plant and engineering
  - Administration and general personnel providing accounting, payroll, human relations, safety and training, stores and purchasing, and other services
  - Management and supervisory staff in all areas.

Estimate Exclusions (OPEX)

- Mining and ore delivery;
- Replacement cost (e.g. mobile equipment);
- Some government charges;
- Royalties
- Taxation costs;
- Marketing costs;
- Escalation cost;
- Contingency;
- Corporate consultancies and
- Duties, customs or other imposts.

Conclusions

- A conceptual engineering study has been completed by SNC Lavalin for the SALT processing plant and associated residue storage facility.
- Capex of $282 MUS$ for a plant to treat 2,000,000 tpa (dry) of below cut – off grade saprolite (at 1.33% Ni) to produce 14,800 tpa of Ni in MHP
- $19,000 US/annual t of Ni production or $8.66 US/annual lb of Ni production.
- Opex from ore to MHP of $3.60 US/lb of Ni.
- Treatment of SALT MHP in Fe-Ni or matte smelting operation to be confirmed
- Environmental aspects of SALT have been designed and costed
- Leach residues are expected to be benign when placed in the residue storage facility.
- Excess solution from the plant is treated to ensure all quality standards for ocean outfall disposal are met (Mn < 1 mg/L)

Next Steps

1. Bench test characterization of new resources followed by integrated, continuous pilot testwork to confirm design criteria.

2. Trade-off study for sulphuric acid and power sources. Acid import versus on site.

3. Identify and test low cost limestone supply.

4. Locating and testing lower cost MgO sources. The testing should include reactivity and performance in synthetic process solutions.

5. Confirm representativity of samples from defined resource of below cut off grade saprolite.

6. Infrastructure assessment for at brownfields site to complete scope and cost. This would include mine, port and MHP feed system to the smelter.

SALT Development Road Map

2011 -2013
- Bench Scale Testing - Completed
- InCoR Purchases Technology

Dec 2013 – March 2014
- Engineering Scoping Study- SNC Lavalin

June 2014 – Oct 2014
- Negotiate terms for pilot plant feed material
- SGS Lakefield Pilot Plant

2015 - 2016
- Feasibility Study

2016
- Go Commercial

For More Information and Testing

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