Direct Nickel Process – Breakthrough Technology

May 2015
Introduction
Thinking Time

- $\text{MgO} + \text{H}_2\text{O} = \text{Mg(OH)}_2$
- $\text{NiSO}_4 + \text{Mg(OH)}_2 = \text{MgSO}_4 + \text{Ni(OH)}_2$
- $\text{Ni(NO}_3)_2 + \text{Mg(OH)}_2 = \text{Ni(OH)}_2 + \text{Mg(NO}_3)_2$
- $\text{Mg(NO}_3)_2 = \text{MgO} + \text{NO}_2 + \text{NO}_2 + \text{O}_2$
DNi

The Nickel World
The Nickel Market

Declining refined production is expected from 2015-2017. New projects needed through 2019 if supply is to keep pace with demand.

- The global nickel market is expected to be in deficit between 2015 and 2019, after a near 50% cut in Chinese NPI production due to the Indonesian ore export ban.
- Beyond 2019, even with the development of new projects, including a replacement NPI sector in Indonesia, world nickel demand will continue to outstrip the supply.
- 775kt of new nickel is required by 2030 to maintain a reasonable market balance.

Source: Wood Mackenzie

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Indonesia’s Impact Yesterday

Indonesian ore destinations in 2013 - before the ban
China dominant; Japan, Australia & Ukraine also important

Source: Wood Mackenzie

Trusted commercial intelligence
© Wood Mackenzie
Nickel Uses

Stainless dominates nickel use and growth

2013 world nickel use by application:
- Stainless: 70%
- Non-ferrous: 10%
- Plating: 7%
- Alloy steel: 5%
- Castings: 3%
- Others: 5%

Stainless share in primary nickel use:

Source: INSG, Macquarie Research, November 2014
Nickel Resources

World resources on Land

Primary Nickel Production

28% Laterite
72% Sulphide

58% Laterite
42% Sulphide
Ni Production Cost Structure

Dispelling the myth
“low grade high cost laterite projects…”

Ore processed head grades

Operating costs pre by product credits

Source: Wood Mackenzie

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Nickel Laterite Processing

<table>
<thead>
<tr>
<th>SCHEMATIC LATERITE PROFILE</th>
<th>COMMON NAME</th>
<th>APPROXIMATE ANALYSIS (%)</th>
<th>EXTRACTION PROCESS</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Ni</td>
<td>Co</td>
</tr>
<tr>
<td></td>
<td>RED LIMONITE</td>
<td>&lt;0.8</td>
<td>&lt;0.1</td>
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<tr>
<td></td>
<td>YELLOW LIMONITE</td>
<td>0.8 to 1.5</td>
<td>0.1 to 0.2</td>
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<tr>
<td></td>
<td>TRANSITION</td>
<td>1.5 to 2</td>
<td>0.02 to 0.1</td>
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<td>SAPROLITE/GARNIERITE/SERPENTINE</td>
<td>1.8 to 3</td>
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<td></td>
<td>FRESH ROCK</td>
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**HPAL**

\[ \text{NiSO}_4 + \text{Mg(OH)}_2 = \text{MgSO}_4 + \text{Ni (OH)}_2 \]

- **HIGH PRESSURE ACID LEACHING**
- Sulphuric Acid
- 260° C
- 600kPa
- Output: MHP, NiS, Ni Metal, Co

- **LOCATIONS**
  - Murrin Murrin
  - Ravensthorpe
  - Ambatovy
  - Goro
  - Ramu River
  - Coral Bay/Taganito

**Figure 1: PAL Flowsheet for Limonite**
CARON PROCESS

- CARON PROCESS
- Ore Drying and Grinding
- Reduction Roast
- Ammonia Leach
- Output: MSP, Nickel metal, NiO, Ni (CO₃)₂, CoS

- LOCATIONS
  - Cuba
  - Brazil
  - Townsville, Qld

Figure 3: Caron Flowsheet for Limonite
RKEF

- ROTARY KILN ELECTRIC FURNACE
- Drying and Crushing
- Calcination and Reduction
- Electric Smelting
- 1200-1600°C
- Large Energy Demand
- Output: FeNi (20-25%Ni)

- LOCATIONS
  - Greece
  - Brazil
  - New Caledonia
  - Indonesia

Figure 4: RKEF Smelting Flowsheet for Saprolite
The DNi Process Flow Sheet & Test Plant Program
A Compelling Business Case

Direct Nickel has developed a game changing process for extracting nickel from laterite deposits. It will position Direct Nickel as one of the lowest cash cost producers in the global nickel industry in the next 5 years. The Process offers unparalleled cost efficiency, capital savings and environmental benefits.

Why is there an opportunity?

- Nickel is a US$30 billion a year industry.
- The demand for nickel is growing and supply is threatened.
- Nickel sulphide discoveries are declining yet there is an abundant supply of laterite resources
- In Jan 2014 Indonesia banned nickel laterite ore exports
- Existing High Pressure Acid Leach (HPAL) and ferronickel processes are struggling with CAPEX, OPEX, technical risk, delays and commercial failure
- Indonesian Government wants downstream processing

DNi offers a new proprietary processing solution that will position the Company among the lowest cash cost nickel producers in the next 5 years that are able to meet the growing global demand.
How Does DNi Process Performs?

- One flowsheet for the entire laterite ore profile
- Atmospheric pressure, 304 stainless construction
- Recovers 90-95% Ni in 1 to 4 hours residence time
- Much lower technical intensity than HPAL and smelting — easier implementation
- Recycles reagent (+95%), environmentally friendly
- Reduced waste disposal - suited to tropical locations
- No scale-up thresholds (profitable from 5ktpa Ni)
- Produces Mixed Hydroxide Product MHP (45+% nickel) or alternative product specifications
- DNi holds world-wide, perpetual licence for the DNi process with world patents and a sophisticated IP strategy
DNi Process – Simplified Schematic

\[ \text{Ni(NO}_3\text{)}_2 + \text{Mg(OH)}_2 = \text{Ni(OH)}_2 + \text{Mg(NO}_3\text{)}_2 \]
Test Plant Layout
Test Plant Design

- Plant was designed to treat 1 tonne per day of laterite ore
- Successfully treated a range of ores from Indonesia – 100% saprolite, 25% limonite/75% saprolite, and 50% limonite/50% saprolite – and a 50% limonite/50% saprolite ore blend from Brazil
- Operated for 11 months over 19 campaigns where operation was continuous for 24 hours. Campaigns ranged from 10 days to 28 days.
- Fully tested a range of equipment in continuous service including pumps, tanks, thickeners, piping, agitators and general materials of construction.
- Majority of plant is constructed from 304L stainless steel.
Barren Evaporation, Decomposition and Acid Recovery

\[ \text{Mg(NO}_3\text{)}_2 = \text{MgO} + \text{NO} + \text{NO}_2 + \text{O}_2 \]
Test Plant – Overall Performance

- High standards of occupational health, safety and environment were demonstrated
- High Recovery of Nickel to MHP
- Recovery of Nitric Acid – 95%+
- MHP Grade Achieved 30-40%Ni
- Fe Grade Produced – 59wt% Fe
- MgO Quality – 95%+ MgO, 50 seconds Citric Acid Reactivity
- Plant maintenance simple, only 2 areas of corrosion where 304L may not be the correct selection
- Process showed flexibility with variable feed sources
Sustainability Features

• Recycles main consumables, nitric acid and MgO
• Fully utilises nickel resources
• Recovers valuable by-products
• Small waste footprint
• Waste is benign and “tropical-proof”
• Rehabilitation simple and effective
• Zero water discharge project
• Simple effluent processing if required
Products
Based on Test Plant results and subsequent lab tests and modelling results, the following MHP and MOP would be produced:

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<thead>
<tr>
<th></th>
<th>Ni</th>
<th>Co</th>
<th>Al</th>
<th>Fe</th>
<th>Mg</th>
<th>Ca</th>
<th>Cr</th>
<th>Mn</th>
<th>Si</th>
<th>NO₃</th>
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<td>1.6</td>
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<td>1.8</td>
<td>0.1</td>
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<td>0.02</td>
<td>6.0</td>
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<td>1.7</td>
<td>2.3</td>
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## MgO Co-Product

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<th>Value</th>
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<tr>
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<tr>
<td>Fe</td>
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<td>NO₃</td>
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<td>Citric Reactivity</td>
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**Hematite Co-Product**

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<td>Cr</td>
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<td>Si</td>
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<tr>
<td>Mg Ca K</td>
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<tr>
<td>Na Ni Ti</td>
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<tr>
<td>Co Cu Zn</td>
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<td>P$_2$O$_5$</td>
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<tr>
<td>Sc</td>
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<tr>
<td>p80</td>
<td>µm 20</td>
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PT Antam/PT Direct Nickel Joint Venture
Nikel Halmahera Timur
Buli Feasibility Study
DNi’s first plant targeted for Indonesia

Indonesia is the perfect location for DNI as it:

- Has very high nickel grades (1.5% to 2.5%) and the greatest aggregate endowment of laterite nickel (>34Mt) in the world
- Has abundant laterite at grades under 1.8% which is often currently treated as waste, but would be high grade material elsewhere, and is ideal for the DNi Process
- The Indonesian government has banned the export of unprocessed ore from January 2014, to encourage value added processing in Indonesia
- Indonesia has a strong mining culture
- Nikel Halmahera Timur (NHT) is a company owned equally by subsidiaries of PT ANTAM and DNi, whose sole purpose is to develop the Tanjung Buli resource base using the DNi Process

The first commercial DNi plant can be built in Indonesia
Project Location - Buli
Mining at Tanjung Buli
2013: 8.5wMt of ore = 130,000t Ni
Buli Feasibility Study Scope

- Uses low grade ore mined with high grade production
- 5,000 to 20,000 tpa Ni production in the form of MHP/MOP
- Feed 1.5Mdt at 1.6 – 2.0%Ni
- Existing facilities include jetties, constructions camps, workshops
- Coal fired power plant and steam co-generation
- 9 month program includes 3 Test Plant Campaigns
- Excellent data base from FHT Project
- Currently funding constrained
- 210,000 tpa of MgO and 310,000 tpa of Fe₂O₃
Conclusions
Conclusions

The DNi Process:

- Has significant advantages over alternative laterite technologies:
  - Very low cost of production,
  - Applicable to the whole ore body – extending mine life
  - With lower cost of production, a lower cut off grade can be applied if necessary – extending resource size
- Whilst “new” concepts, uses conventional consumables and equipment
- Has been demonstrated on a continuous basis
- Has excellent environmental credentials
- Ready for commercialisation

MgO is a key component in hydrometallurgy
The DNi Process – What Do we Offer?

The DNi Process is an atmospheric hydrometallurgical process developed to treat the full laterite profile (from limonitic to saprolitic ores) and is believed to be the only process capable of doing so economically.

1. Compelling Economics of DNi Unique Process

<table>
<thead>
<tr>
<th>Capex</th>
<th>Opex</th>
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<tbody>
<tr>
<td>$35++ HPAL, FeNil</td>
<td>$5-8/lb other processes</td>
</tr>
<tr>
<td>$35 US$ per pound of annual capacity</td>
<td>$2.00- 3.00/lb DNi</td>
</tr>
<tr>
<td>$12.50 DNi</td>
<td>$2.00- 3.00/lb DNi</td>
</tr>
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</table>

2. Treatment of full laterite profile

- **Atmospheric leaching**: no applied pressure and moderate heat
- **A breakthrough process**: Treats both limonite and saprolite in same flow sheet
- **IP protection strategy to ensure exclusivity**:

3. Superior Environmental Performance and Efficiency

- **Recyclability**: the unique feature of the DNi Process is the ability to recover over 95% of the reagent for re-use in the process, significantly reducing operating costs, minimising tailings and lessening environmental impact.

*All DNi costs independently produced by Aker Solutions (now Jacobs Engineering). Comparisons show DNi Processing to MHP, ~75% of LME.*
Direct Nickel’s strategy is to license its revolutionary process technology in joint venture with owners of nickel laterite deposits such as PT Antam in Indonesia and Oro Nickel in PNG.

**Timeline**

- **2005**
  - Foundation
  - Development and licence agreement with Drinkard Metalox Inc

- **2006**
  - Teck & Oz Minerals invest $8.5m

- **2008**
  - Positive Aker Solutions PFS2

- **2009**
  - Successful commercial scale Recycle Demonstration (USA)

- **2010**
  - Construction of Perth Test Plant
  - CSIRO 1st equity investment

- **2012**
  - Co-operation Agreement with PT Antam, Indonesia
  - CSIRO invests a further $2.1m in equity

- **2013**
  - TECK funding Test Plant with further investment & technical support
  - Technology proven

**Key Events**

- **2008**
  - Positive Aker Solutions PFS2

- **2010**
  - Construction of Perth Test Plant

- **2012**
  - Co-operation Agreement with PT Antam, Indonesia

- **2013**
  - TECK funding Test Plant with further investment & technical support

**Total funding committed to date is over $40M**
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