Identification and determination of factors encountered in marine minerals processing, influencing world metal markets

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Interoceanmetal

- **Pioneer contractor**, Zone Clarion - Clipperton, in 2016 the exploration contract was extended for five years
- **International Organization**; the member of Interoceanmetal, IOM: Poland, Bulgaria, the Russian Federation, Cuba, the Czech Republic and Slovakia
Currently IOM develops the optimization of three technologies for the metallurgical processing of polymetallic nodules:

– **Hydrometallurgical Process** of Acid Leaching using sulfur dioxide as a reducer

– **Pyro - hydrometallurgical processing**; obtaining Mn-rich slag and subsequent hydrometallurgical treatment of Ni, Co, and Cu alloys

– **Hydrometallurgical**; HPAL process according to the technology of the Moa Bay plant, Cuba, using pyrite as a reducer and the extraction of Ni, Co, Cu and Zn with the "Resin in Pulp"
Hydrometallurgical Processing
Central Institute of geological studies of non-ferrous and precious metals, Moscow, RF

Conceptual stage

Water → Leaching → Cu, precipitation → Ni + Co, precipitation → Mn, precipitation

Leaching

Solid/liquid → Tailing → Scu (sale) → Sn + SCo(sale) → Mn(sale) → Drying, Briquetting and melting → (NH₄)₂SO₄ (sale)

Grinding → Leaching → Cu, precipitation → Ni + Co, precipitation → Mn, precipitation

H₂SO₄, SO₂, S⁰, SO₂ Flocculant, Flocculent

Drying,
Hydrometallurgical Processing
Lab tests; basic results

Extraction; %

Mn - 70
Ni – 97,5
Co – 92,5
Cu – 92,5

Sulfuric acid consumption
290 - 310 Kg / ton. PN
Pyro - Hydrometallurgical Processing
University of chemical and metallurgical technologies, Sofia, Bulgaria

Conceptual stage

Coke \downarrow \quad \text{Lignite} \downarrow

- Preparation
  - Drying
  - Grinding
  - Agglomeration

- Selective melting
  - Mn – rich slag

- Complex alloy
  - Ni, Co and Cu

- Dissolution and precipitation Cu
  - Separation
  - Liquid/Solid

- Ca (OH)$_2$ \downarrow

- \text{Tailing}

- \text{Neutralization of the solid phase}

- \text{NH}_3 \downarrow

- \text{H}_2\text{S} \downarrow

- \text{SCu(sale)}

- \text{SNi + SCo (sale)}

- \text{Precipitation Ni + Co}
  - Separation
  - Liquid/solid
Pyro - Hydrometallurgical Processing
Lab tests; basic results

Extraction, %

In the slag
Mn – 90

In the complex alloy
Ni – 92,0
Co – 93.6
Cu – 92,8

Consumption of electric power
520 - 530 KWh / ton. slag
High Pressure Acid Leaching Process (PN+limonite)

Research center for the mining – metallurgical industry, Havana, Cuba

Conceptual stage

Water \downarrow, H_2SO_4 \downarrow, Pyrite

Pulp preparation
- PN
- Limonite
- Pyrite

HPAL 240°C

Extraction Cu
Resin in Pulp
Adsorption pH 1–1.5 /
Desorption
Precipitation H_2S

Resin Lewatit TP 207

Limestone \downarrow

Zn(sale) \rightarrow SNi +SCo(sale)

Extraction Ni, Co and Zn
Resin in Pulp
Adsorption pH 4–4.5 /
Desorption
Solvent extraction Zn
Precipitation Ni + Co H_2S

Extraction Mn
pH 9
- Autoclave crystallization
- Calcination

SCu (sale)

MnO(sale)

Tailing
HPAL process
Lab tests; basic results

Extraction, %
- **Ni** – 95.5
- **Co** – 92.8
- **Cu** – 90.5
- **Zn** – 92

Sulfuric acid consumption;
320 - 350 Kg / ton of ore + PN
Facilities of the Moa Bay port to receive the polymetallic nodules
Moa Bay metallurgical plant, HPAL process
Other technologies in evaluation process

FeMn production

Mineral mixture + PN

Collaboration with the Company Orava Ferroalloy Works Istebné, OFZ, Slovak Republic.
Other technologies in evaluation process
Production; high purity powders Co, Ni, Zn and Cu

Technology "Carbonyl"

Collaboration with the Canadian Company Chemical Vapor Metal Recovery (CVMR)
Carbonyl technology
Laboratory-scale tests were carried out
Now bench-scale tests are carried out
Economic model
“Order of Magnitude”

✓ In the process of elaboration the first economic model

✓ They will be developed for the five technologies

✓ An internal tool as a first step for economic analysis
Technologies vs. Market

There are many ways to extract metals from Polymetallic Nodules, **but what is the production cost?**
Metals Market

Future increase of metals consumption; general causes

**World population growth (billions)**

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2017</th>
<th>...</th>
<th>2050</th>
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<tr>
<td>World</td>
<td>7</td>
<td>7.3</td>
<td>...</td>
<td>9.9  (1)</td>
</tr>
</tbody>
</table>

**World urbanization increase (%)**

<table>
<thead>
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<th></th>
<th>1957</th>
<th>1967</th>
<th>2014</th>
<th>...</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>21</td>
<td>50/50</td>
<td>54</td>
<td>...</td>
<td>62   (2)</td>
</tr>
</tbody>
</table>

**Development of emerging economies;**

China, India, Russia, Brazil...

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(2) World Urbanization Prospect, 2014, UN – Dep. of Economic and Social Affair
Co and Ni

Batteries

<table>
<thead>
<tr>
<th>Ni : Co: Mn</th>
<th>8:1:1</th>
</tr>
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</table>

| 2015 – 12.2 GWh | ... | 2025 – 36.8 GWh |

Since 2016 more energy accumulated in the batteries of the EV than in other types of batteries

New electric vehicles

| Sold 2018 – 3.1 million in use. | ... | 2030 ~ 125 – 150 millions (3) |

Combustion engines; in a long process of extinction

(3) BMT Research. April 1, 2018
Cobalt; critical case

**Metal sparse**, deficit in 2017, 2018, ... *(5)*

**Risk:** ~60% occurs in a single country, not very stable

**EU:** Regulation 2017/821 - Due Diligence towards supplier countries at risks or in conflicts (including child labor)

*Deep Sea mining; could be solution for shortage of Co*

*(5) Bloomerg New Energy Finance. 18.05.2018*
Geographical composition of metal production and consumption

Geographical composition of metal production and consumption

(global percentage shares in 2016)

a) Production

b) Consumption

Sources: Bloomberg and ECB calculations.
In the middle of the way

✓ Questions to be answered in our Project

✓ Cooperation with Universities, Research Centers and Production Companies

Interoceanmetal focuses on 2021!

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... in the middle of difficulty lies the opportunity...
(A. Einstein 1879 – 1955)