Application of Solvent Extraction Technology in the Nickel Industry

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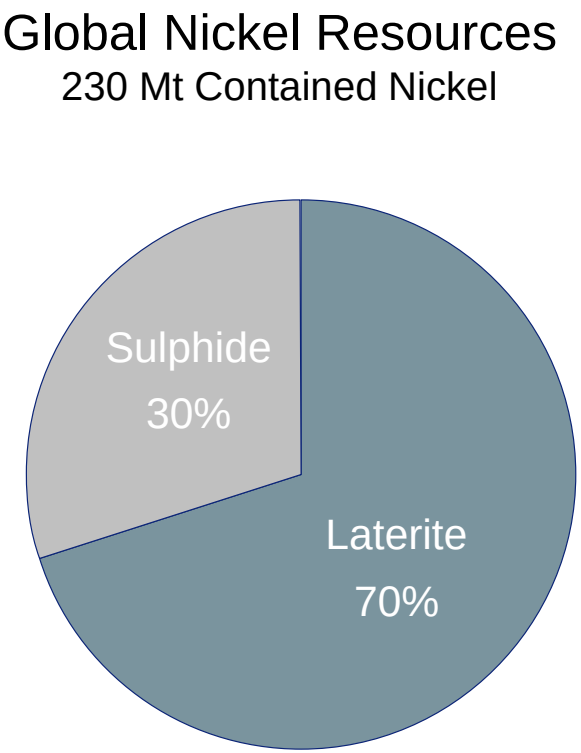
Presentation Outline

- Nickel resources
- Technology (from ore to metal)
- Medium (aqueous solutions)
- Reagents for the SX-technology
- Examples of applications
- Typical equipment used in SX-processes in the Ni-industry

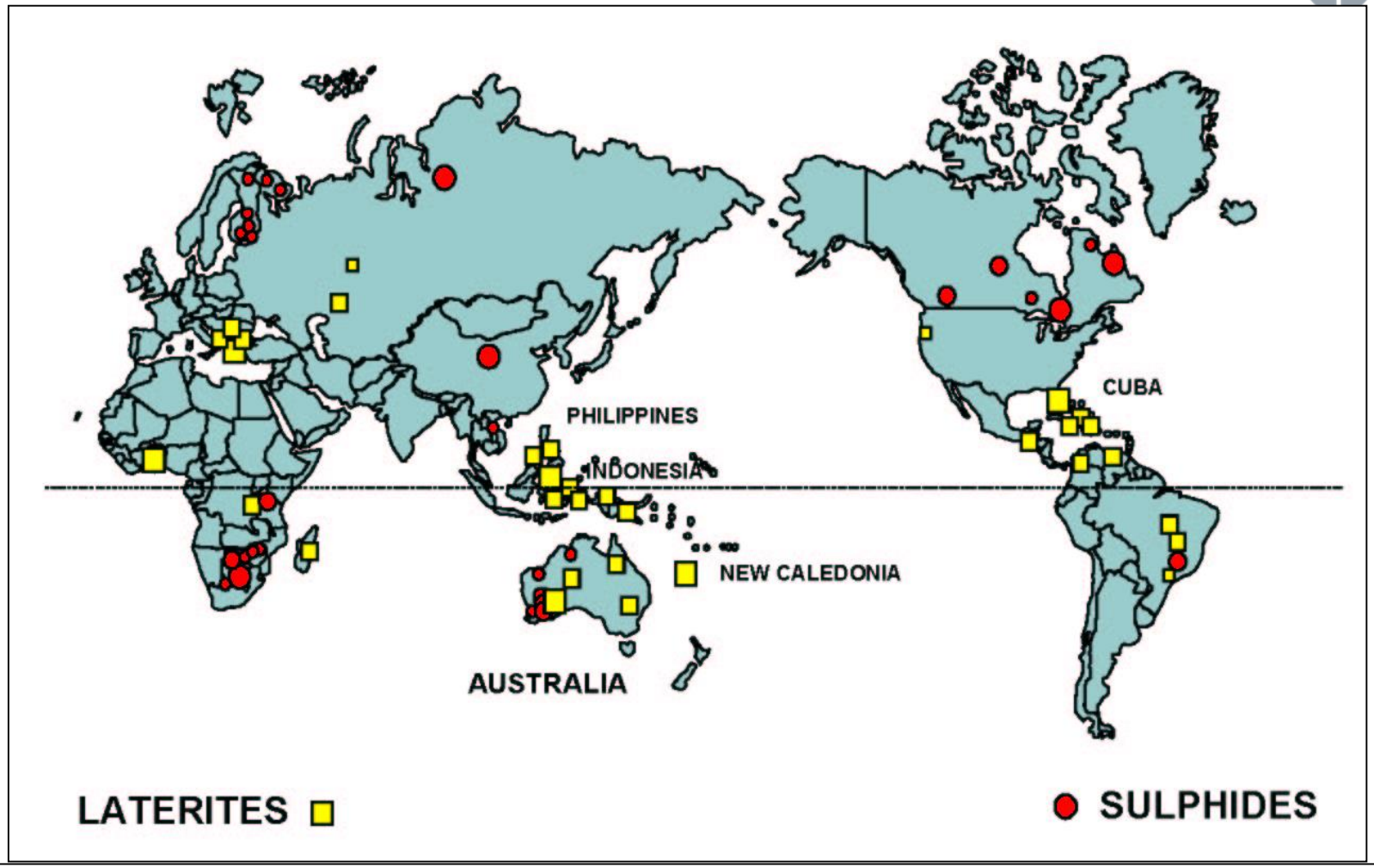
Global Ni resources



R/P = 230/2.3 ~ 100 yrs

Apparantly no lack of resources…

Distribution of global nickel resources



Technology used from ore to metal

For sulphide nickel resources

1. Milling – produce Ni concentrate ("Ni-con")
   - Crushing, grinding, flotation etc.

2. Pyrometallurgy – melt Ni-con to Ni-matte
   - Roasting, el. furnace smelting, converting
   - Flash furnace smelting, converting

3. Hydrometallurgy – refine Ni-matte to Ni metal
   - Electrorefining, soluble anodes (Hybinette)
   - Cl2-leaching – electrowinning, make Ni-cathode
   - HCl-leaching, pyrohydrolysis, make Ni-powder
   - O2/H2SO4-leaching, electrowinning – make Ni-cathode or H2-red. – make Ni-powder & briquettes
   - Air/NH3-leacning, H2-reduction – make Ni-powder & briquettes

4. Vapour metallurgy - refine Ni-matte to Ni metal
   - Chemical vapor depositon - Ni-carbonyl / Ni(CO)4

5. Hydrometallurgy – refine Ni-con to Ni metal directly
   - O2/H2SO4 pressure leach – electrowinning

6. Hydrometallurgy – refine Ni-ore to Ni intermediates
   - Air/H2SO4 bacteria-assisted heap leach – produce NiS intermediate

SX-technology is used in most hydrometallurgical flowsheets

Technology used from ore to metal (cont.)

For laterite nickel resources

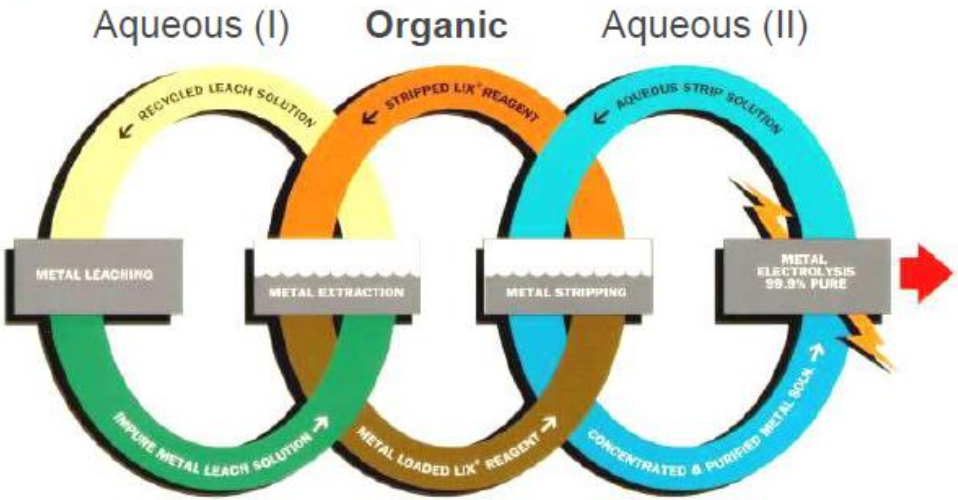
1. Pyrometallurgy – melt "saprolite" to FeNi
   - El. furnace (AC) smelting - RKEF
   - DC furnace smelting ("Koniambo")
2. Pyrometallurgy – melt "saprolite" to Ni-matte
   - El. furnace smelting - RKEF
3. Pyrometallurgy – melt "limonite" to NPI(1)
   - El. furnace
   - Blast furnace
4. Hydrometallurgy – refine limonite ore to intermediate, "primary" or "secondary Ni"
   - HPAL (2)/H2SO4, make MSP(3) or MHP(4)
   - HPAL/H2SO4, electrowinning, make Ni & Co-cathode
   - HPAL/H2SO4, H2-reduction, make Ni & Co powder and briquettes
   - HPAL/H2SO4, pyrohydrolysis, make NiO
   - AL(5)/H2SO4, make MSP(2) or MHP(3)
   - Heap leach/H2SO4, make MSP(2) or MHP(3)
   - Reduction roast, Air-NH3/(NH4)2CO3-leach ("Caron"), make NiO

(1) NPI: Nickel Pig Iron
(2) HPAL: High Pressure Acid Leach
(3) MSP: Mixed Sulphide Precipitate
(4) MHP: Mixed Hydroxide Precipitate
(5) AL: Athmospheric Leach

SX-technology is used in most hydrometallurgical flowsheets

Principles of Solvent eXtraction ("SX")

Solvent Extraction (SX) - the organic is the convenient "shuttle bus" between two aqueous solutions



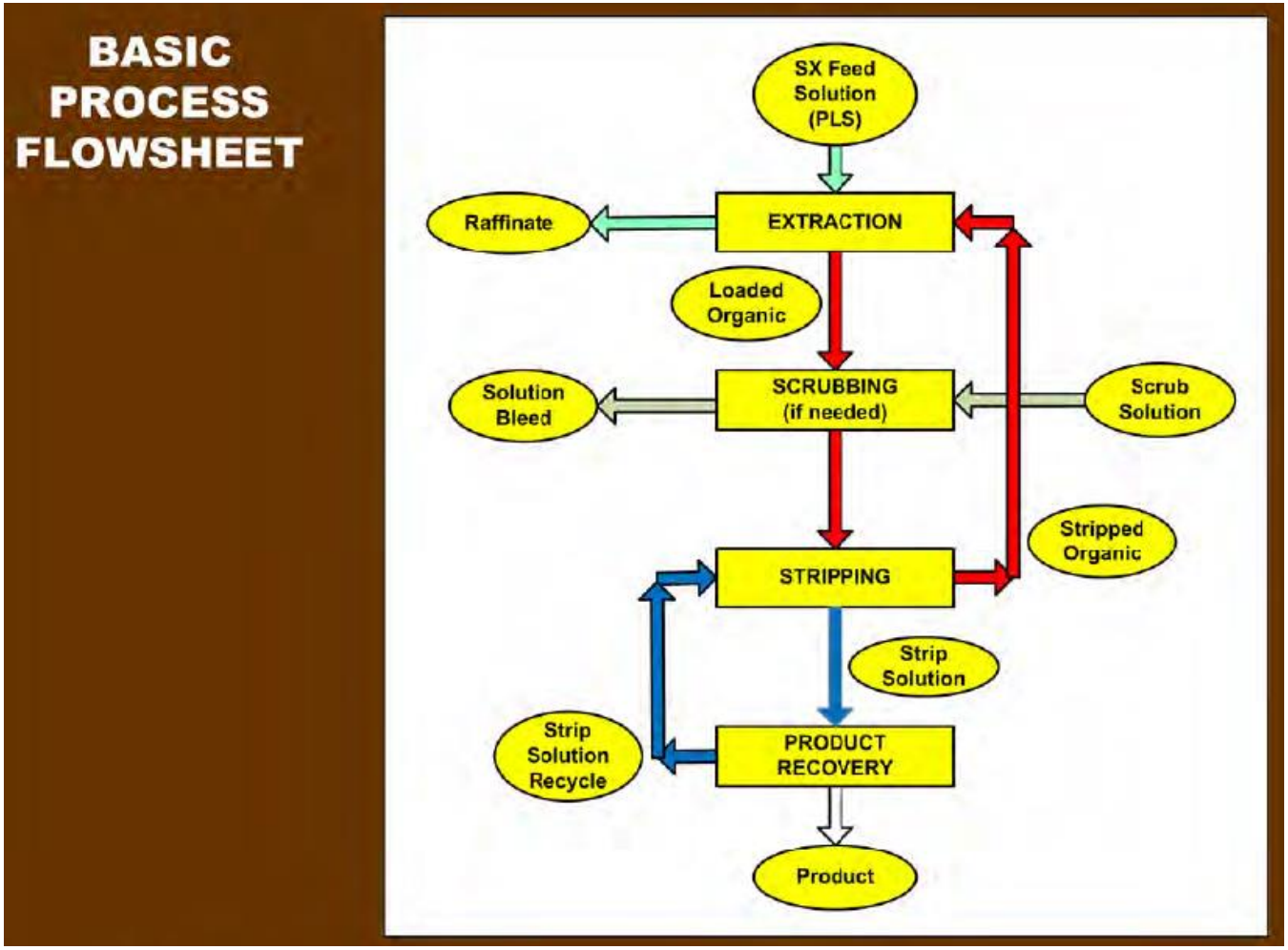
The SX liquid organic phase:

(i) extractant -- the organic chemical reagent reacting with the metal species from the aqueous solution to form a metal-extractant complex which is preferentially distributed to the organic phase

(ii) modifier -- another organic chemical, which improves the solubility of the extractant and/or the metal-extractant complex in the organic diluent, and may also improve the phase separation properties of the SX system

(iii) diluent -- dissolves the extractant (and the modifier) as well as the metal-extractant complex, and provides the required physico-chemical properties of the SX system

Principal SX Flowsheet



Purpose of SX in the nickel industry

1. Separation of Co from Ni
2. Recovery of other by-products
3. Removal of impurities from metal winning Ni-solution
4. Direct solvent extraction of nickel to purify and concentrate the metal winning Ni-solution

Important extractants used in the nickel industry

Suppliers (in Europe), product names

CYTEC, Solvay Group, USA:

CYANEX® 272

CYANEX® 301

BASF, Germany:

Alamine 308® (TIOA)

Alamine 300® (TNOA)

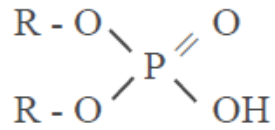
LIX® 84-I

Lanxess, Germany:

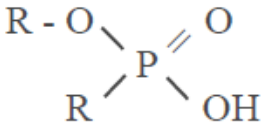
Baysolvex® D2EHPA

Organophosphorus acids as cation exchangers

Organophosphorus acids

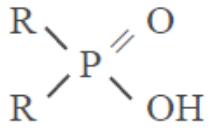
-phosphoric 

D2EHPA

-phosphonic 

PC-88A, Ionquest® 801

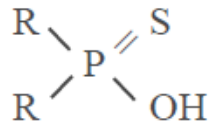
P507

-phosphinic 

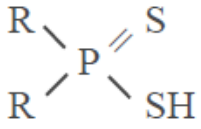
Cyanex® 272, Ionquest® 290

LIX® 272

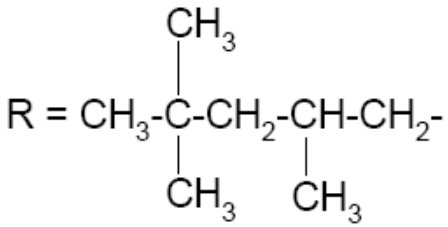
Thio-substituted organophosphorus acids



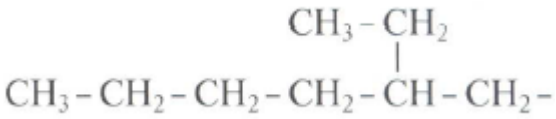
Cyanex® 302



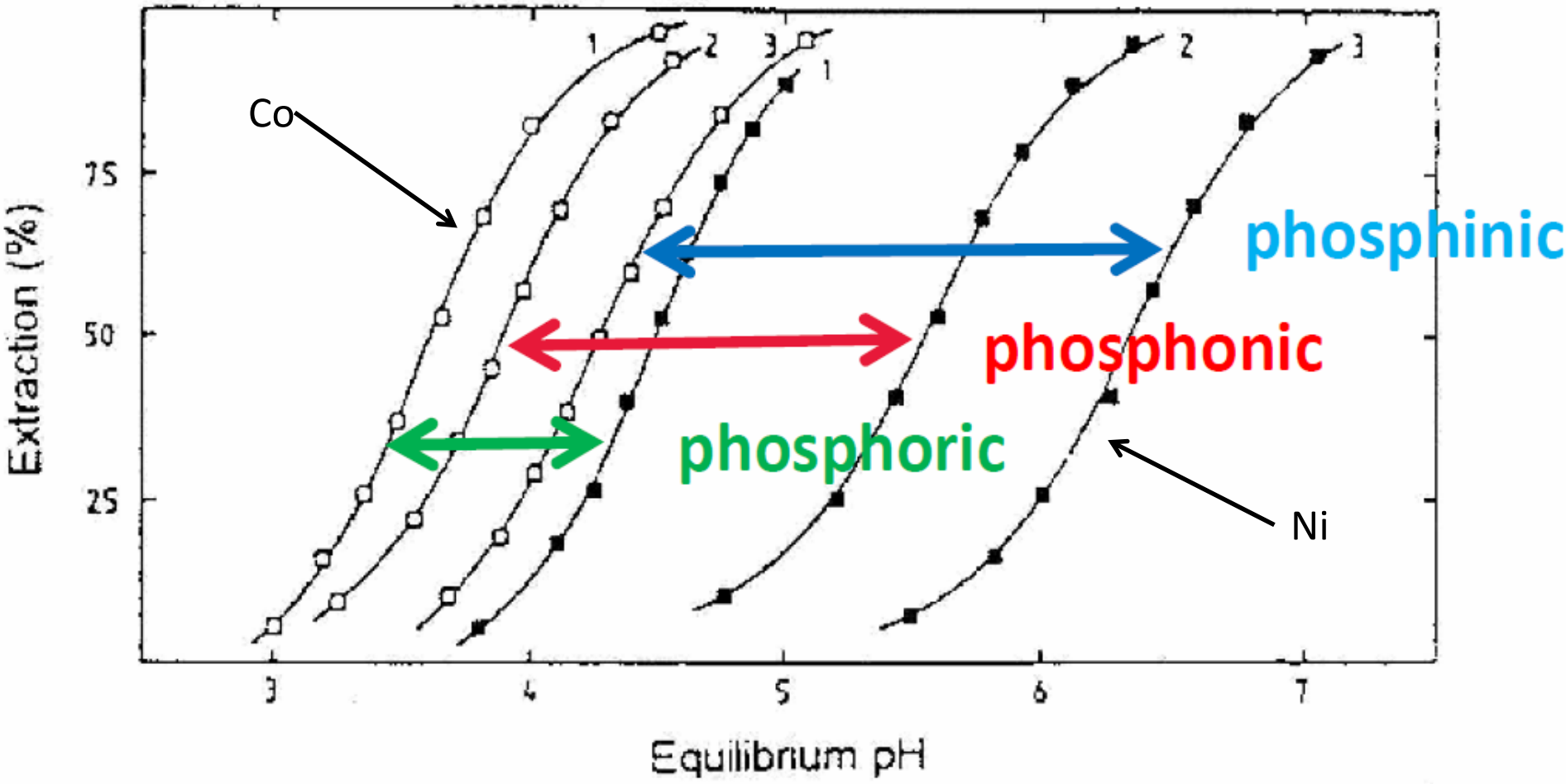
Cyanex® 301



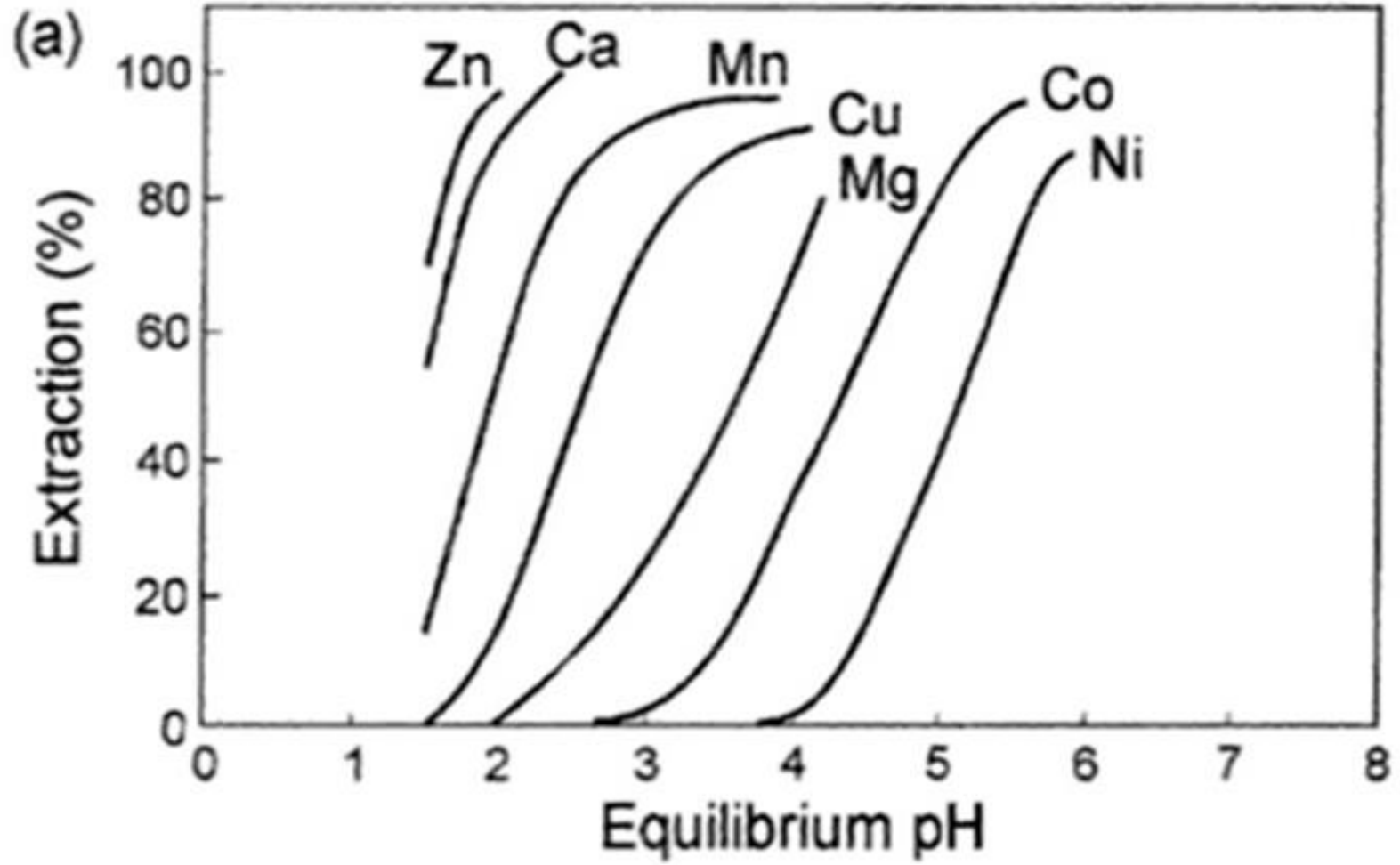
or



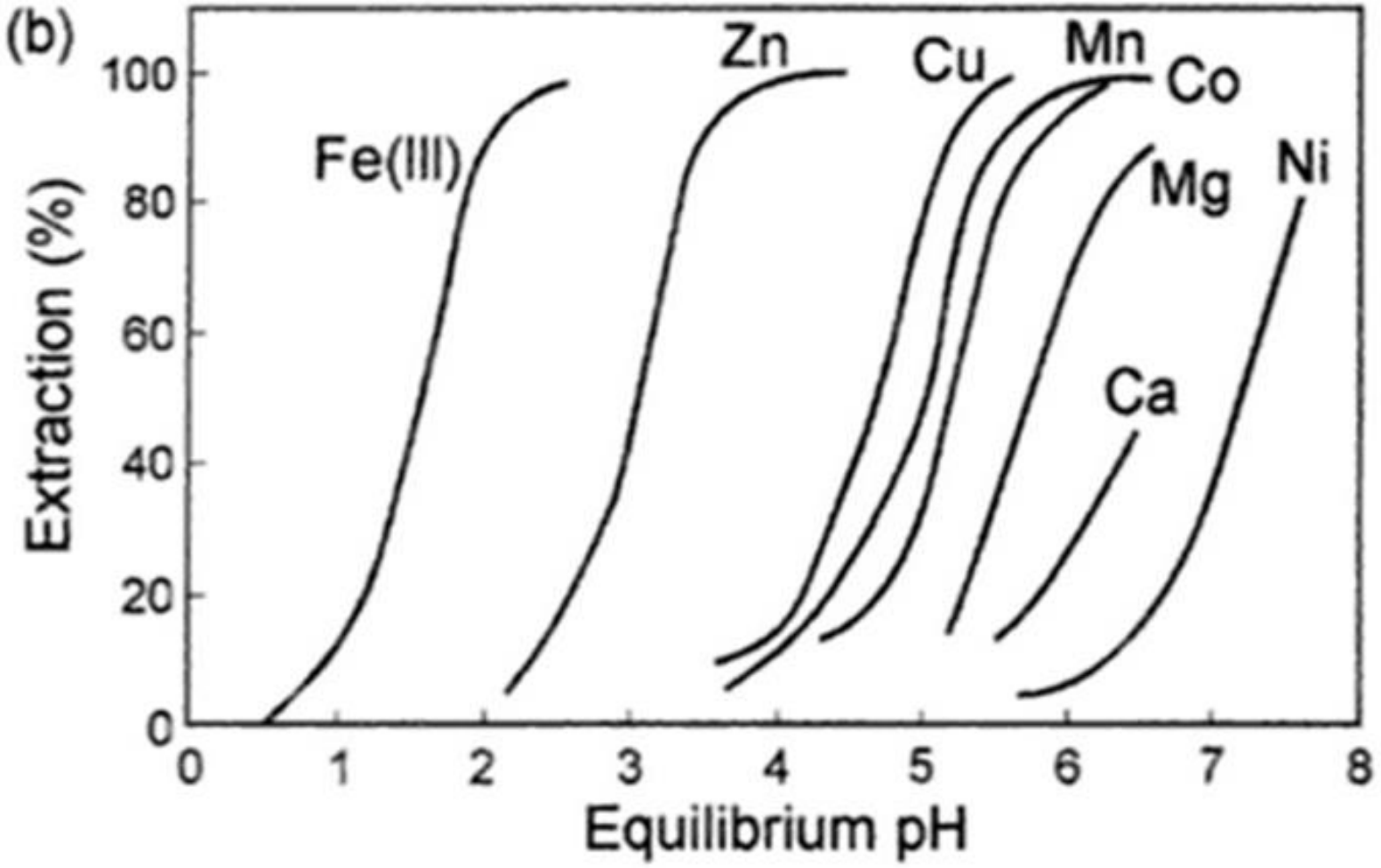
Organophosphorus acids, effect of replacing P – O – C binding with P – C on the separation of Co and Ni



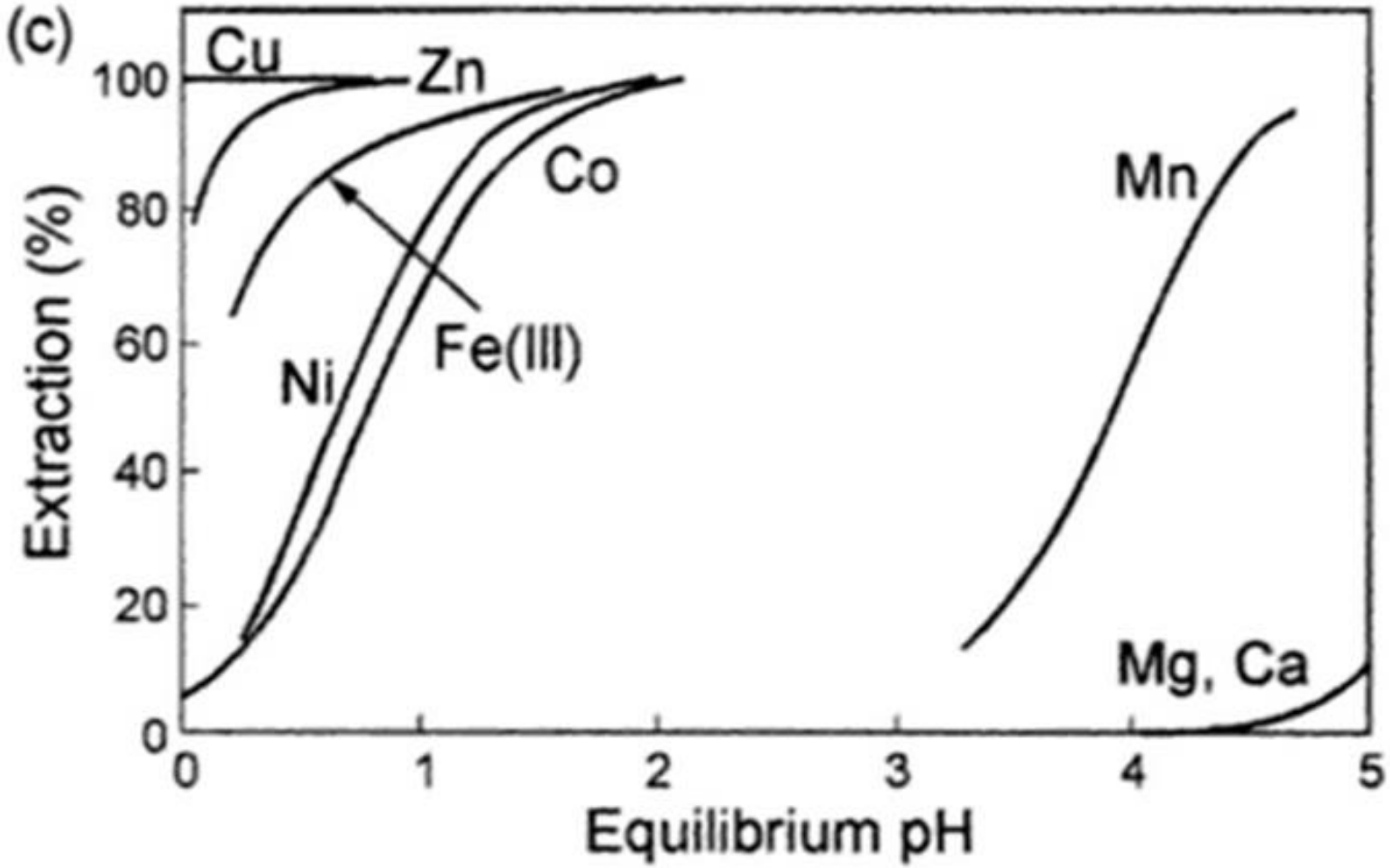
D2EHPA extraction isotherms



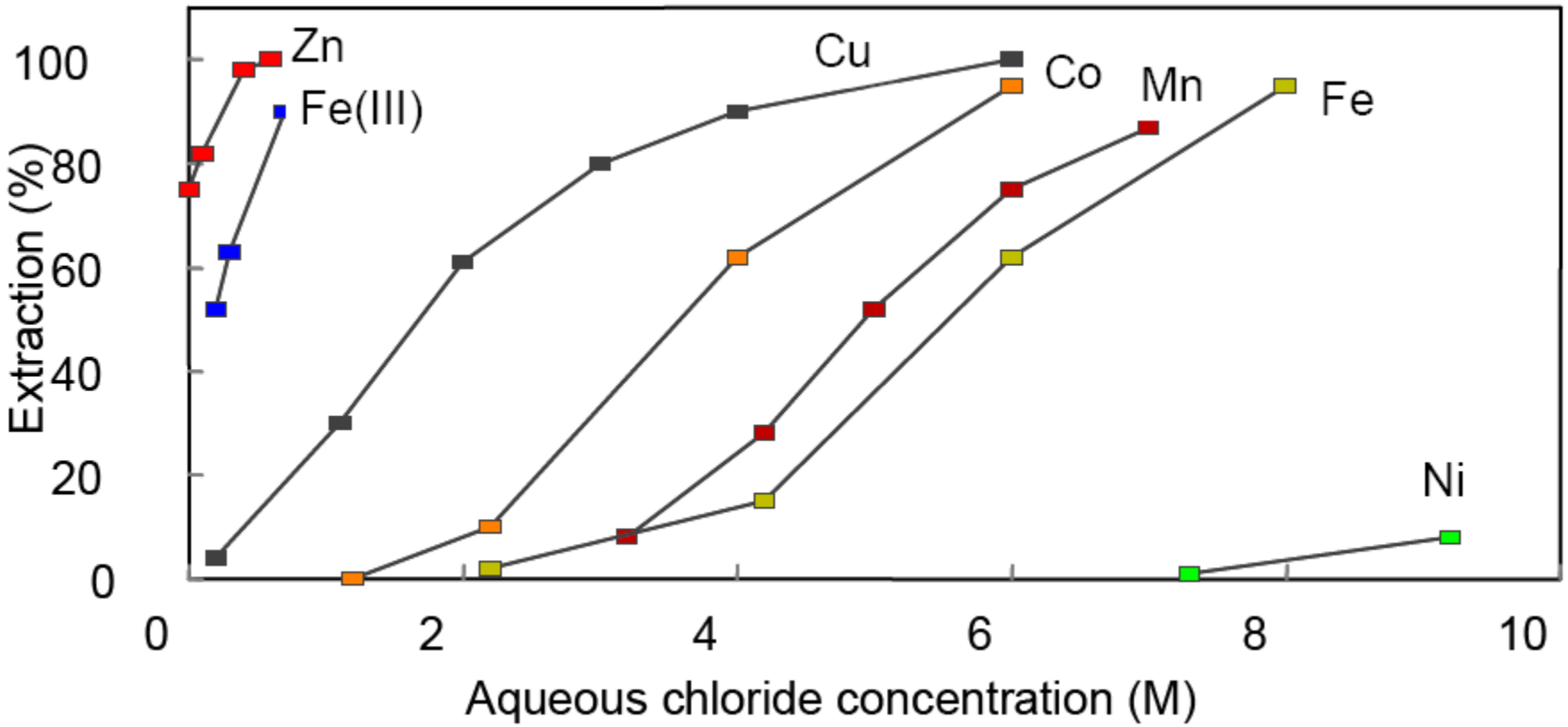
CYANEX 272 extraction isotherms



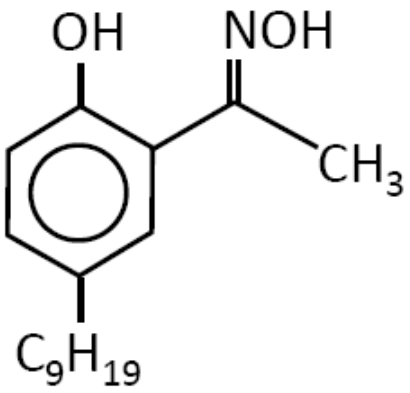
CYANEX 301 extraction isotherms



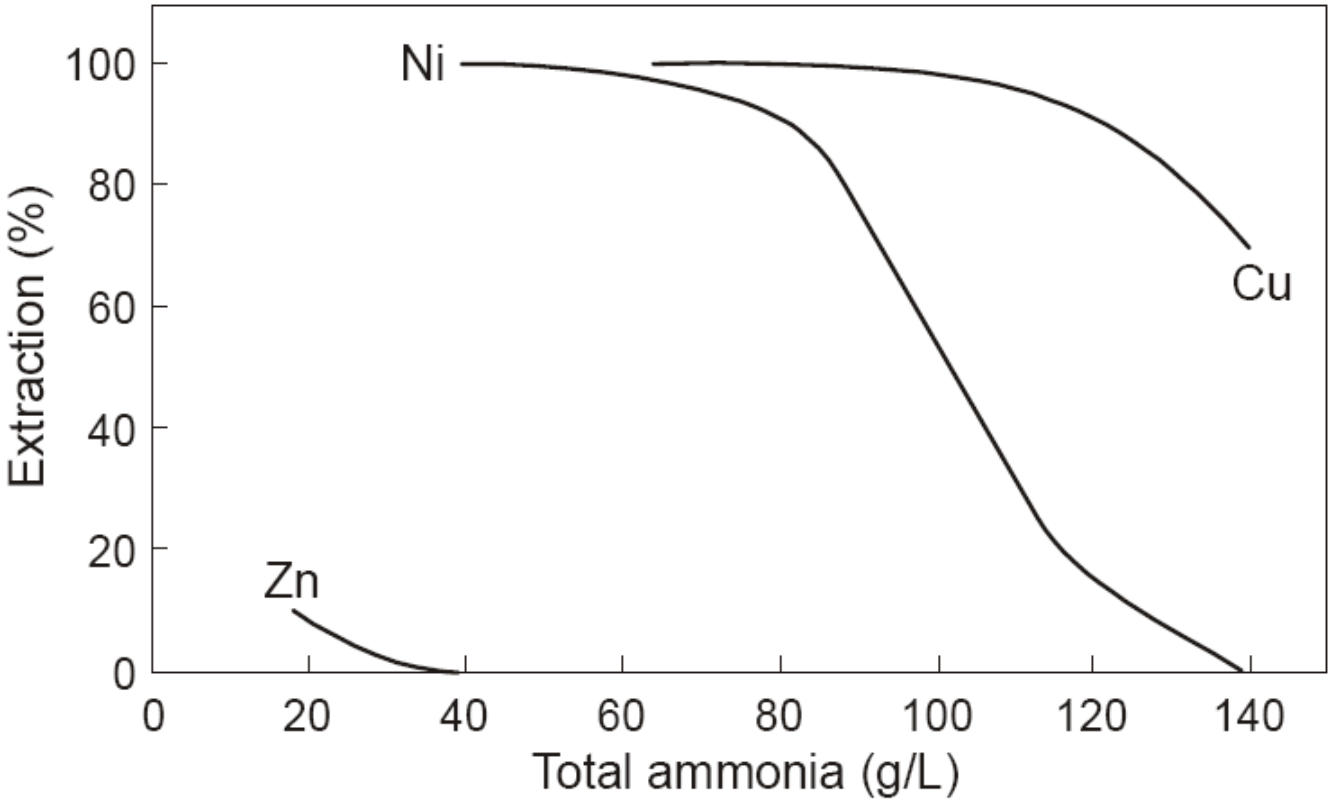
Tertiary amines, TIOA, TNOA



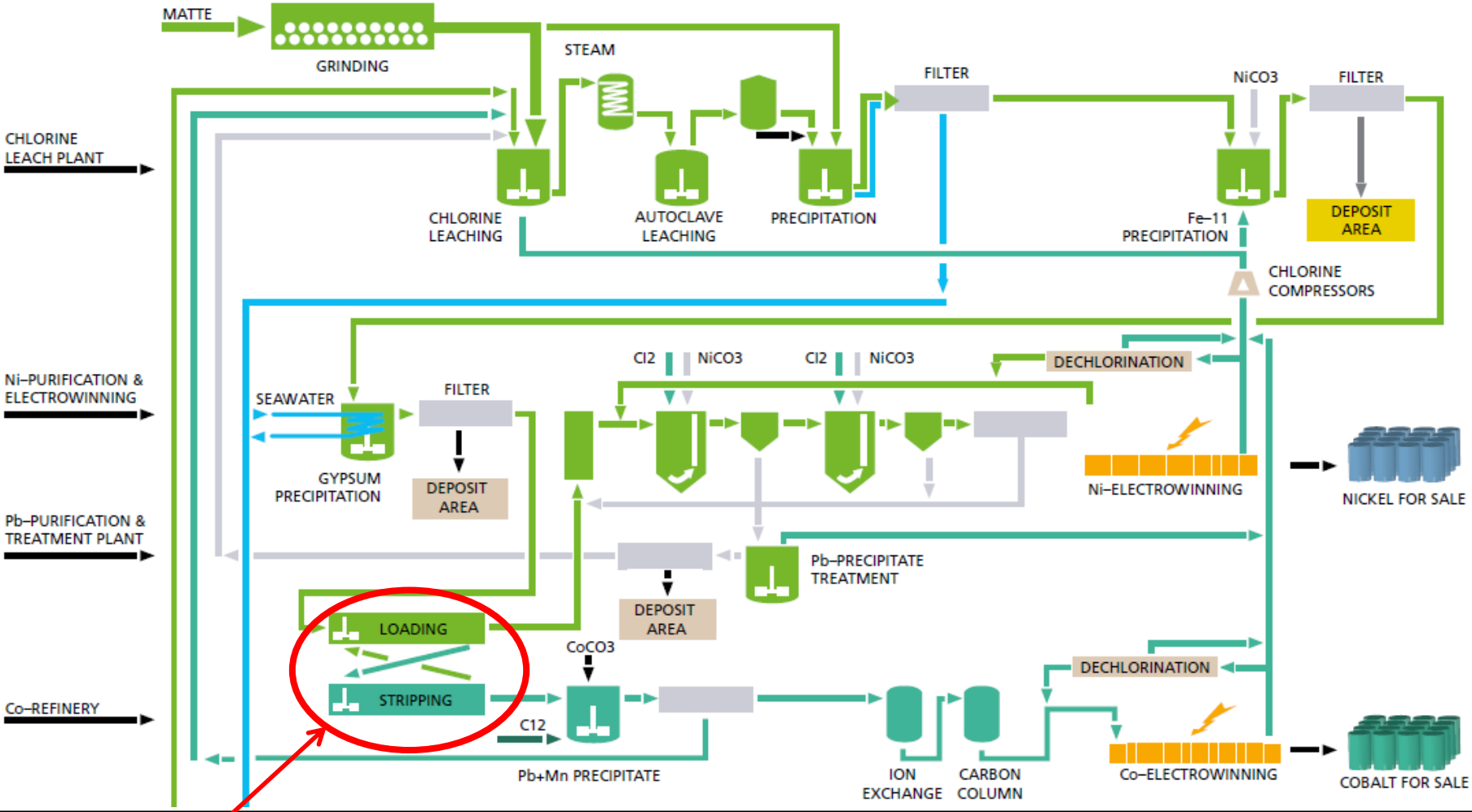
Hydroxy-oxime chelating agents in ammoniacal solutions



LIX 84-I



Glencore Nikkelverk AS, Kristiansand – Cl2 leach-EW, TIOA Co-SX circuit

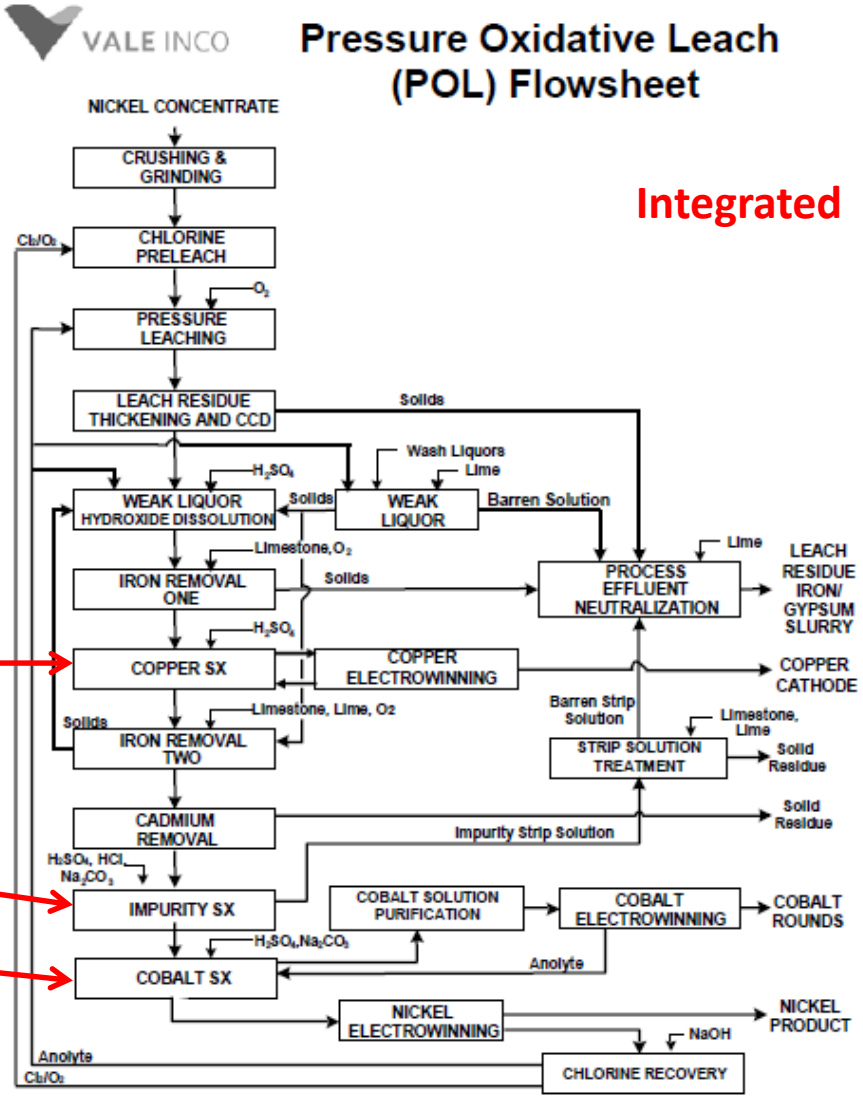


Co-SX

http://www.nikkelverk.no/

NIKKELVERK
A GLENCORE COMPANY

VALE "Long Harbour" O2/H2SO4 Ni-con leach plant in New Foundland, Canada: 3 difference SX-ciruits



Integrated SO4/Cl circuit

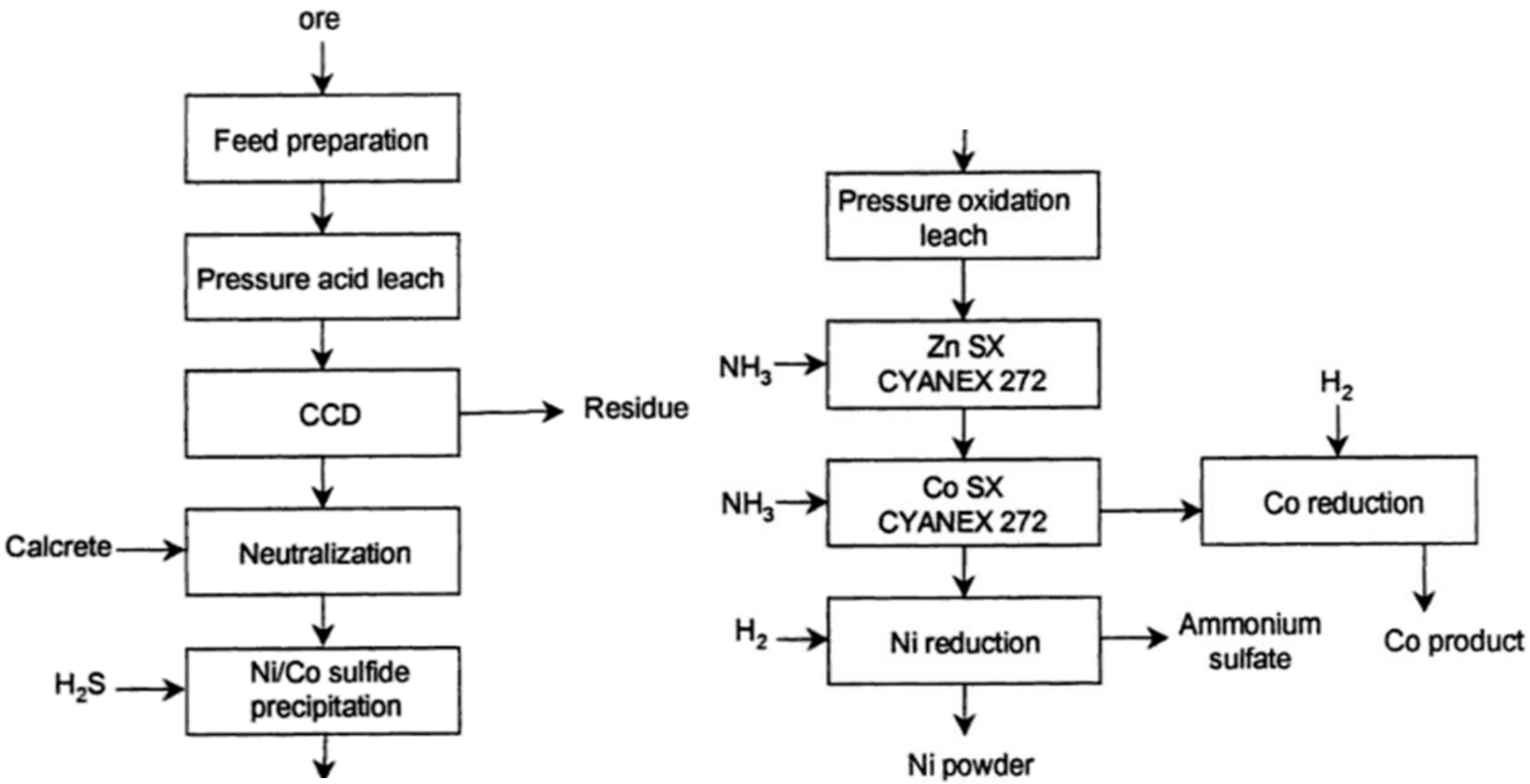
Cu-SX w/LIX

Impurity-SX w/D2EHPA

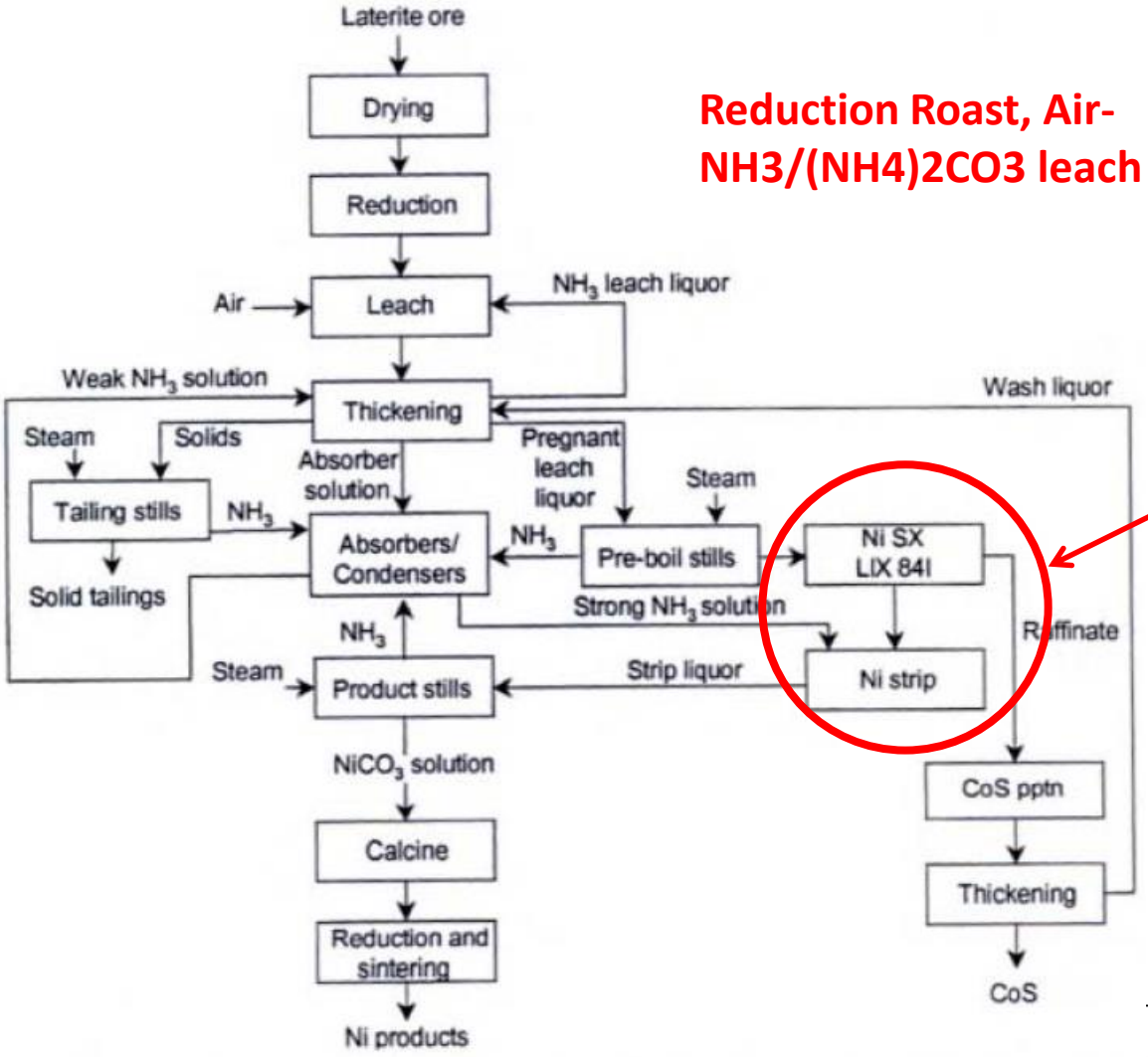
Co-SX w/Cyanex272

NIKKELVERK
A GLENCORE COMPANY

Murrin Murrin – HPAL-flowsheet on limonite ore in W.Australia, CYANEX 272 in 2 circuits



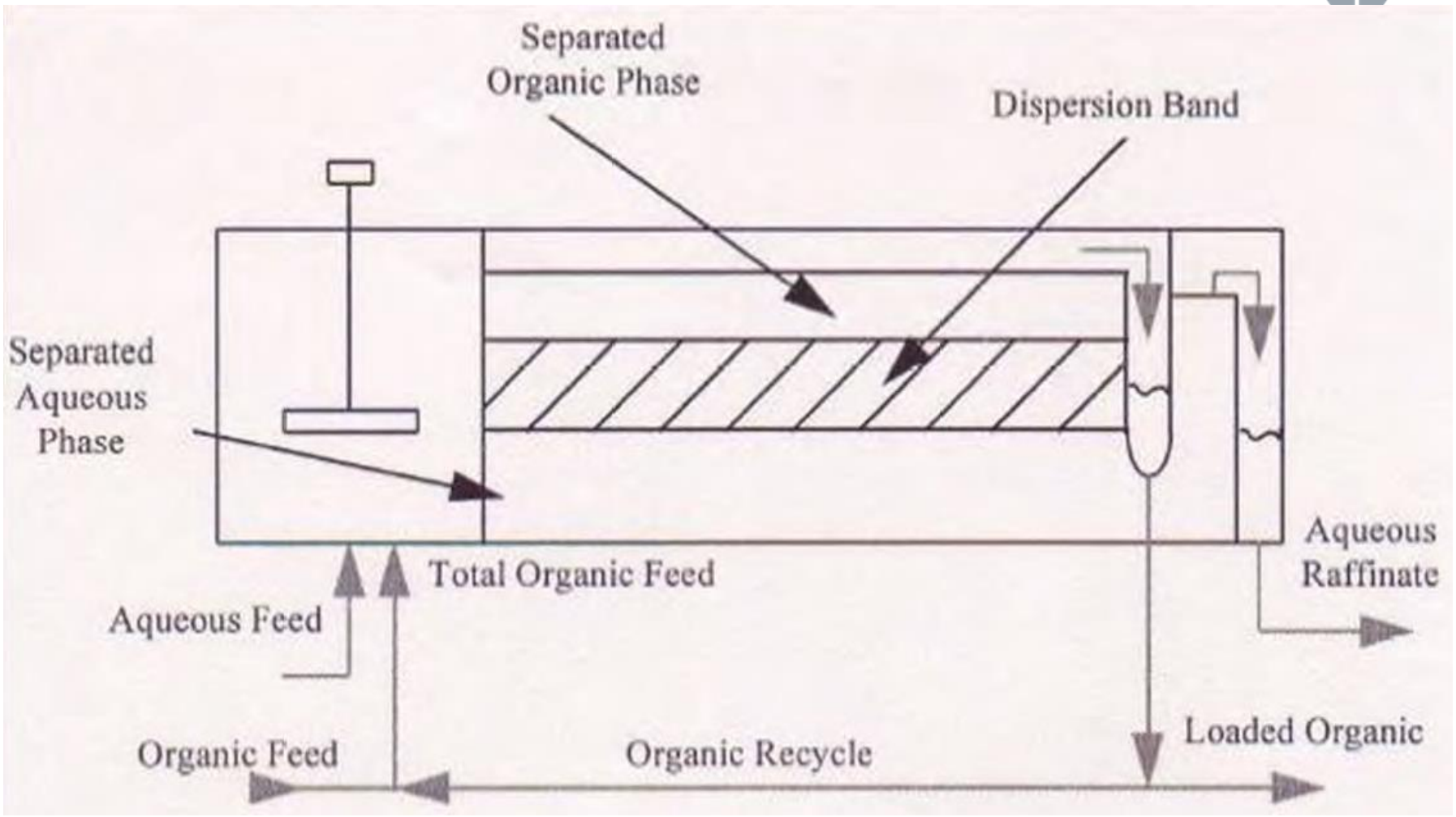
Queensland Nickel, Australia – "Caron" technology with Ni-SX by LIX® 84-I



Reduction Roast, Air-NH3/(NH4)2CO3 leach circuit

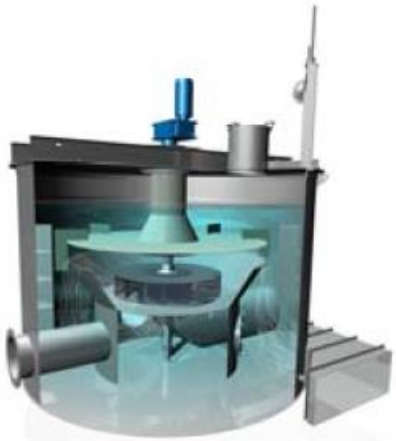
Ni-SX

Principal design of conventional mixer-settler equipment

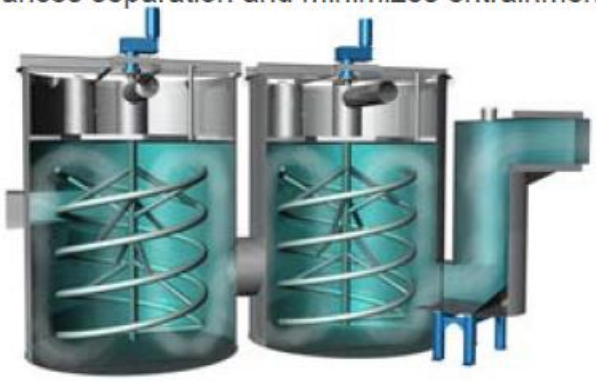


Outotec VSF Mixer Settler

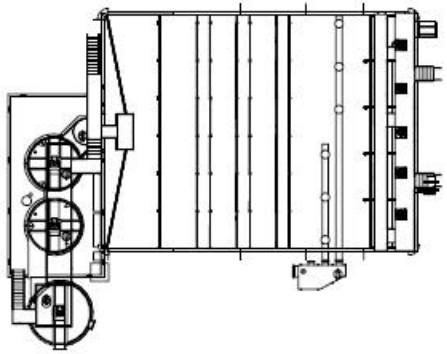
- Separate pumping (DOP – dispersion overflow pump) and mixing (Spirok) in Outotec's Vertical Smooth Flow unit ensures high stage efficiency with no overmixing thus faster phase separation and lower entrainment; use of submerged fences in settler further enhances separation and minimizes entrainment

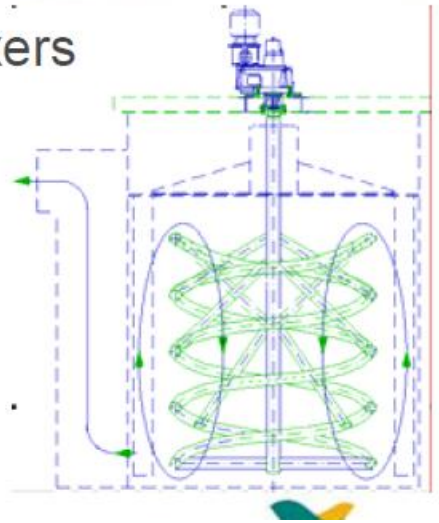


DOP



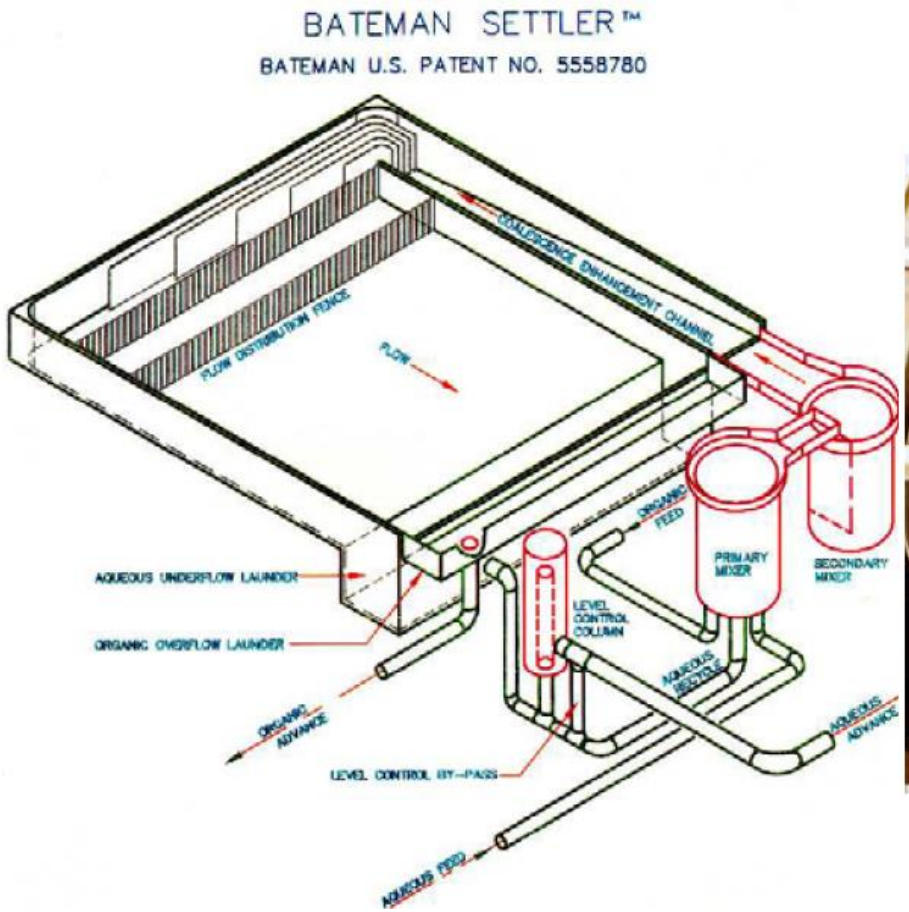
Spirok mixers

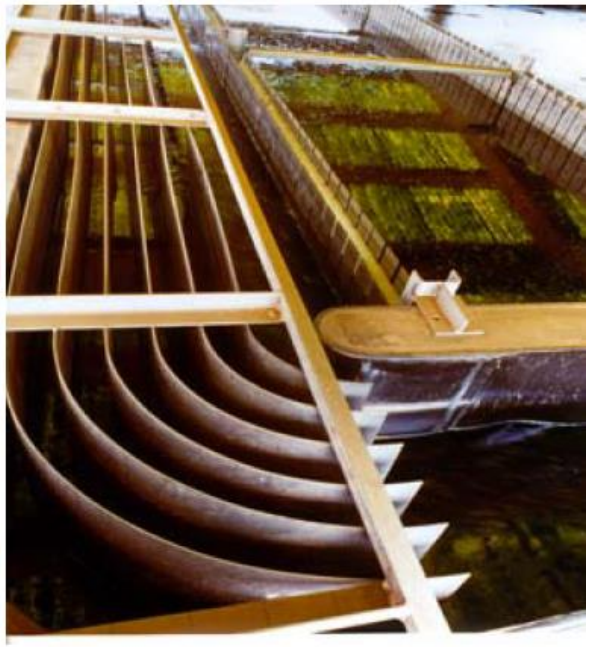




Bateman Reverse Flow Mixer Settler

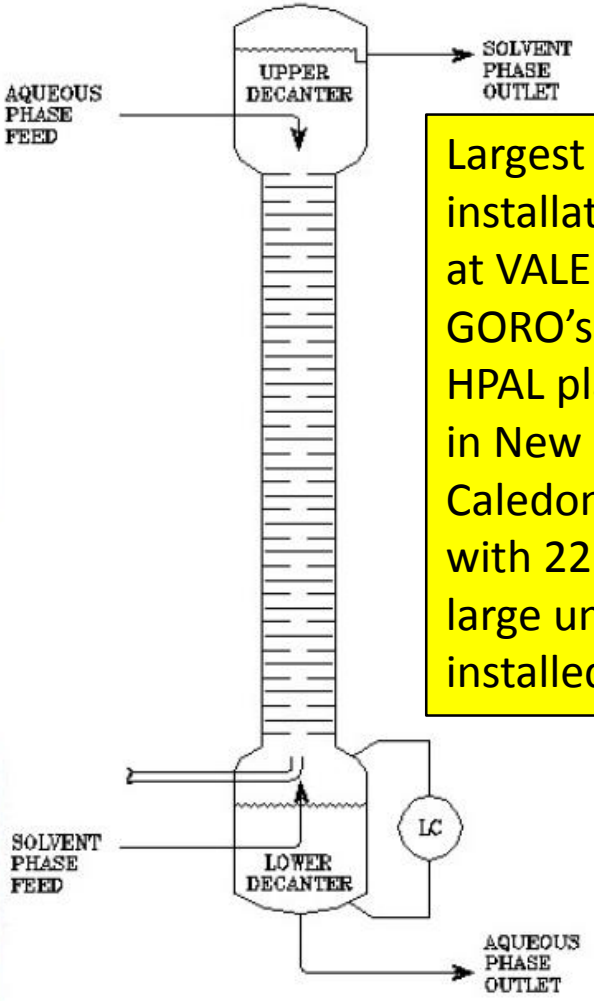
- The Reverse Flow Mixer Settler (RFMS) offers improved separation through the use of the coalescence enhancement channel and the turning vanes; linear flowrates of both phases is maintained the same and without sudden changes in flow direction to minimize turbulence





Bateman Pulsed Column

- Disc/donut pulsed columns with no internal moving parts has been used in the nuclear industry (i.e., in France)
- Bateman has successfully developed further and implemented the technology to the large scale hydrometallurgical refining (extraction columns at Olympic Dam for Uranium SX)



Largest installation at VALE GORO's HPAL plant in New Caledonia with 22 large units installed

Bateman Pulsed Column - details

- Energy for mixing provided by compressed air via an external leg; usually, constant frequency, variable amplitude
- Maintaining dispersed phase hold-up is a key parameter to ensure residence time requirements
- Organic/liquid interface controlled in upper (for aqueous-continuous) or lower (for organic-continuous) decanter