



## AMS Specialty Nanofiltration Membranes in Base Metals Production

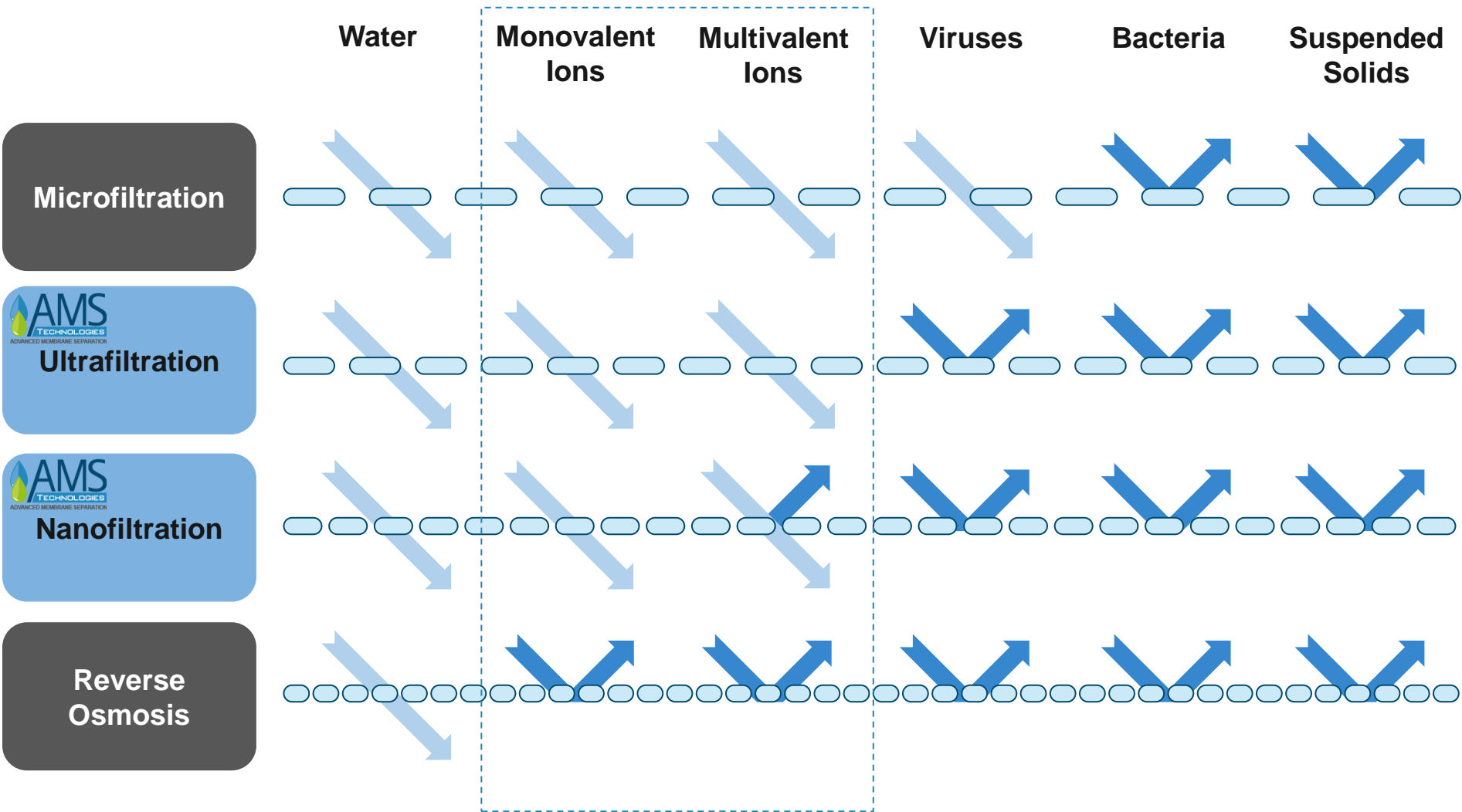
- ✓ AMS Technologies is a commercial membrane manufacturer that specializes in the treatment of in-process and wastewater streams
- ✓ Following a decade of cutting edge research, our team of scientist developed a unique line of highly durable nanofiltration and ultrafiltration membrane products enabling the treatment of aggressive industrial streams with great benefits to clients

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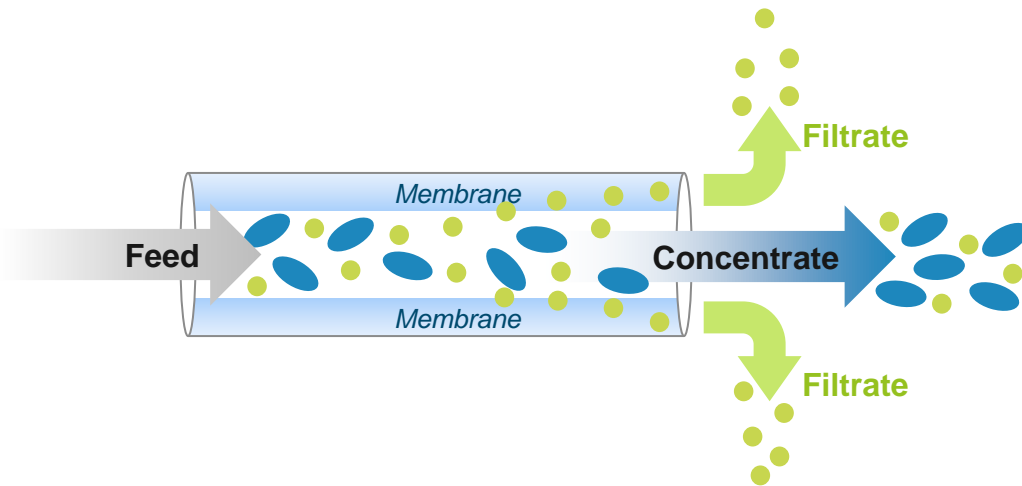
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# Nanofiltration (NF) membranes have rejection selectivity: allowing monovalent and blocking multivalent components



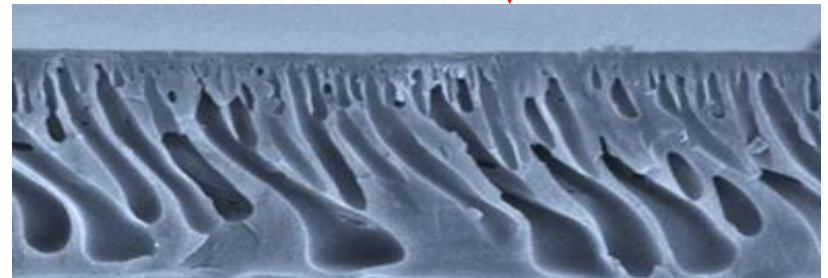
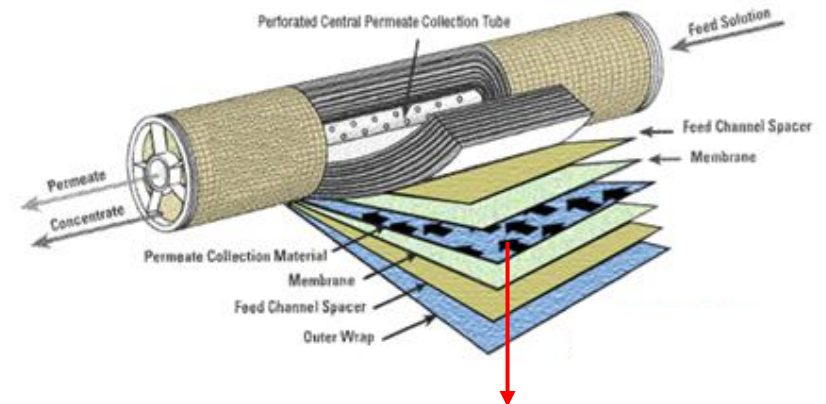
# AMS membranes uniquely designed for metal complex separation under aggressive conditions

NF used to recover acid and concentrate metals

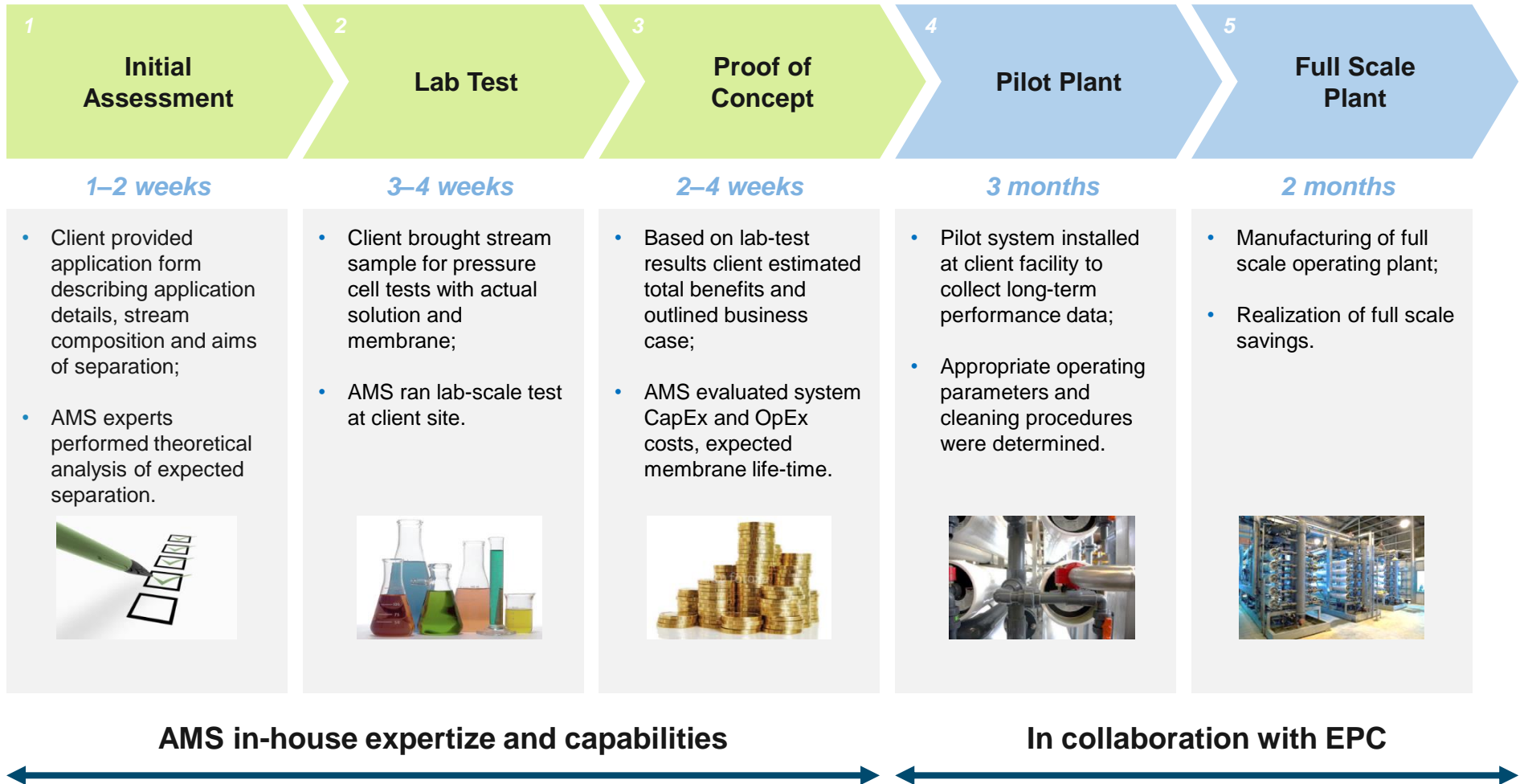


- Small monovalent molecules (e.g. water, acid, caustic)
- Multivalent metal components, organics (e.g.  $\text{CuSO}_4$ ,  $\text{NiSO}_4$ )

Spiral wound modules maximize membrane area per module



# Project approach consists of several stages for better assessment and project risk mitigation



# Spent electrolyte treatment project by AMS brings in USD 2.0 M NPV and 2 years payback

## NF plant scheduled for European EW unit ...

<b>Client</b>	Large Vertically Integrated Copper Producer
<b>Project Region</b>	Eastern Europe
<b>Application</b>	NF treatment of regenerated electrolyte at EW unit
<b>Treatment Vol.</b>	Approx. 20 m <sup>3</sup> /day
<b>Status</b>	Following successful feasibility tests, NF plant commissioning scheduled to 2017

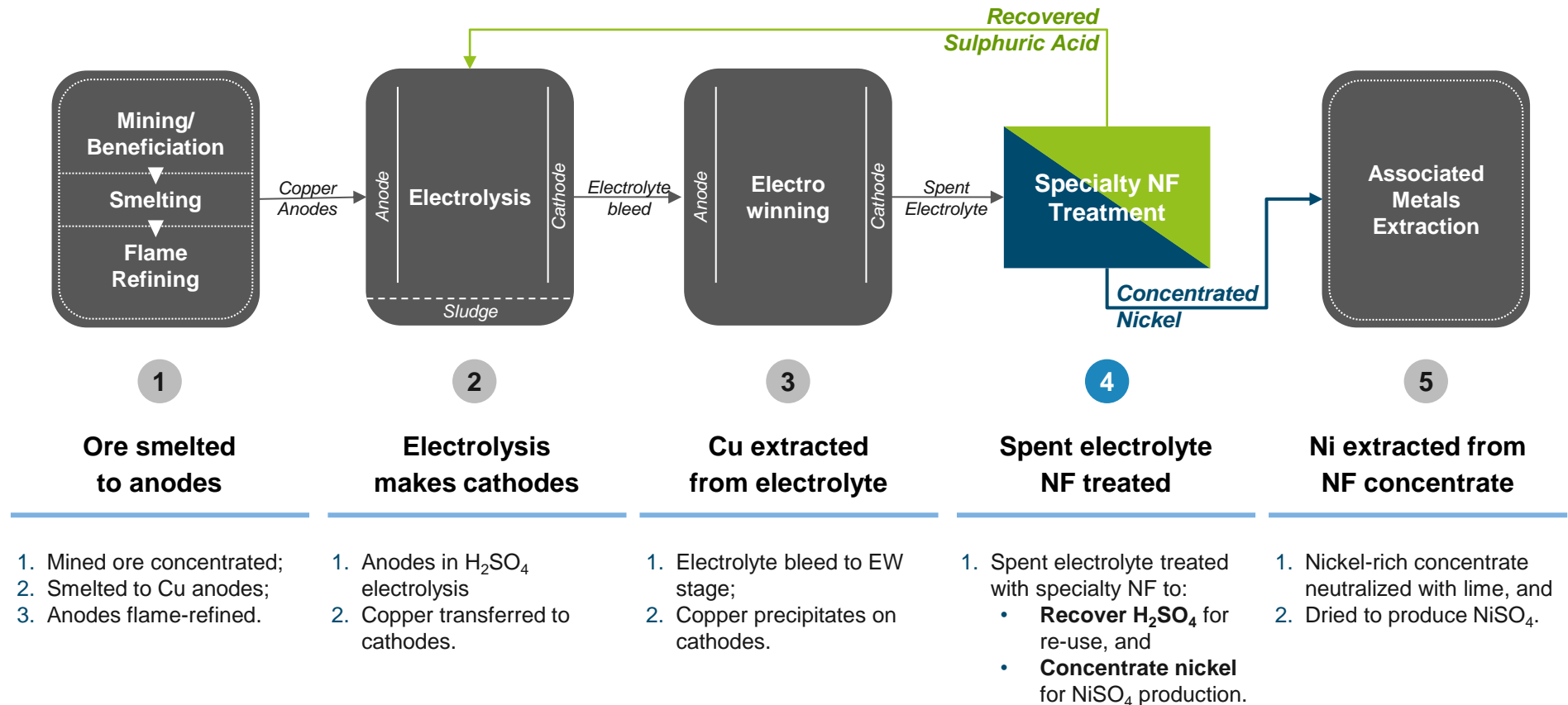
## ... to treat aggressive acid stream ...

<b>Feed Solution</b>	<b>H<sub>2</sub>SO<sub>4</sub>:</b> 284 g/L <b>Cu:</b> 0.20 g/L <b>Ni:</b> 19.6 g/L
<b>Treatment Highlights</b>	<b>H<sub>2</sub>SO<sub>4</sub>:</b> Clean 79% recovery in filtrate <b>Cu &amp; Ni:</b> 96–98% recovery in concentrate, 3 times increase in concentration
<b>Realized Benefits</b>	<ol style="list-style-type: none"> <li><b>Acid recovery</b> enables reuse, decreasing a) acid consumption, b) transportation and handling, and c) heating cost;</li> <li><b>Metals concentration</b> in solution allows to: a) cut neutralization cost, b) increase final product value and price, and c) decrease final product package and transportation costs.</li> </ol>

## ... bringing in NPV of USD 2.0 M with 2 years payback

USD Thousands	Year 1	Year 2	Year 3
<b>Savings</b> calc. by client	146.7	146.7	146.7
<b>CapEx</b>	377.8 <i>Hastelloy plant to sustain 22% H<sub>2</sub>SO<sub>4</sub></i>	0	14.4 <i>Elements replacement once in 2 years</i>
<b>OpEx</b>	2.2 <i>Membrane cleaning and electricity</i>	2.2	2.2
<b>Net CF</b>	(233.3)	144.5	130.1
<b>Total CF</b>	(233.3)	(88.8)	41.3
<b>NPV @ 10% = USD 1'957 K</b>			

# NF employed at base metals plant to recover acid for re-use and concentrate nickel for value addition



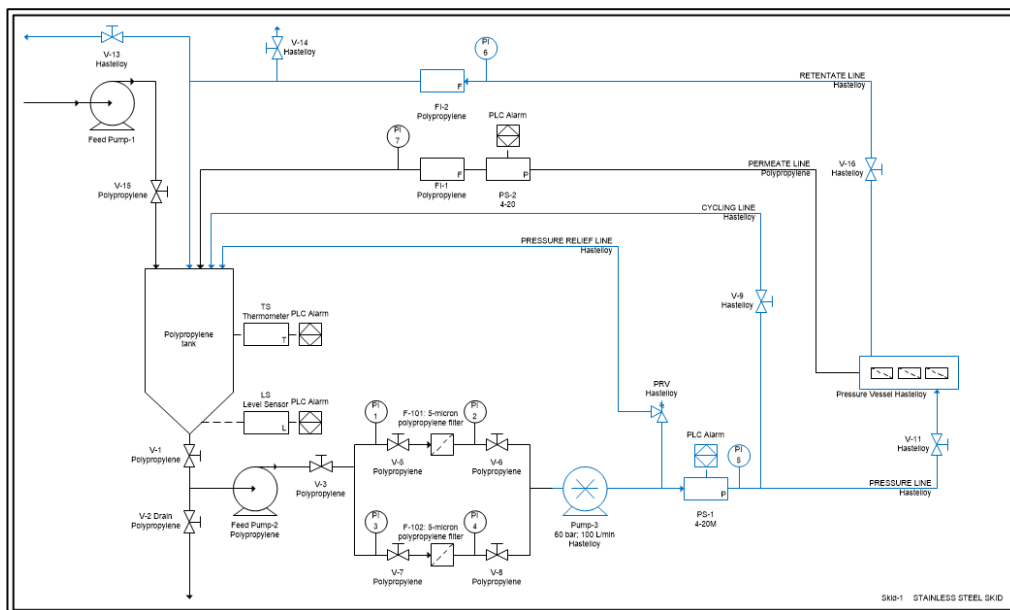
**Membrane treatment brought multiple benefits:**  
**Acid re-use:** lower purchase, transport, handling, heating;  
**Ni Concentration:** less neutralization, higher product value

# Commercial NF system treats 20 m<sup>3</sup>/day of spent electrolyte with high H<sub>2</sub>SO<sub>4</sub> content

NF system was designed ...

... with flexibility and durability in mind

**Scheme of NF system**

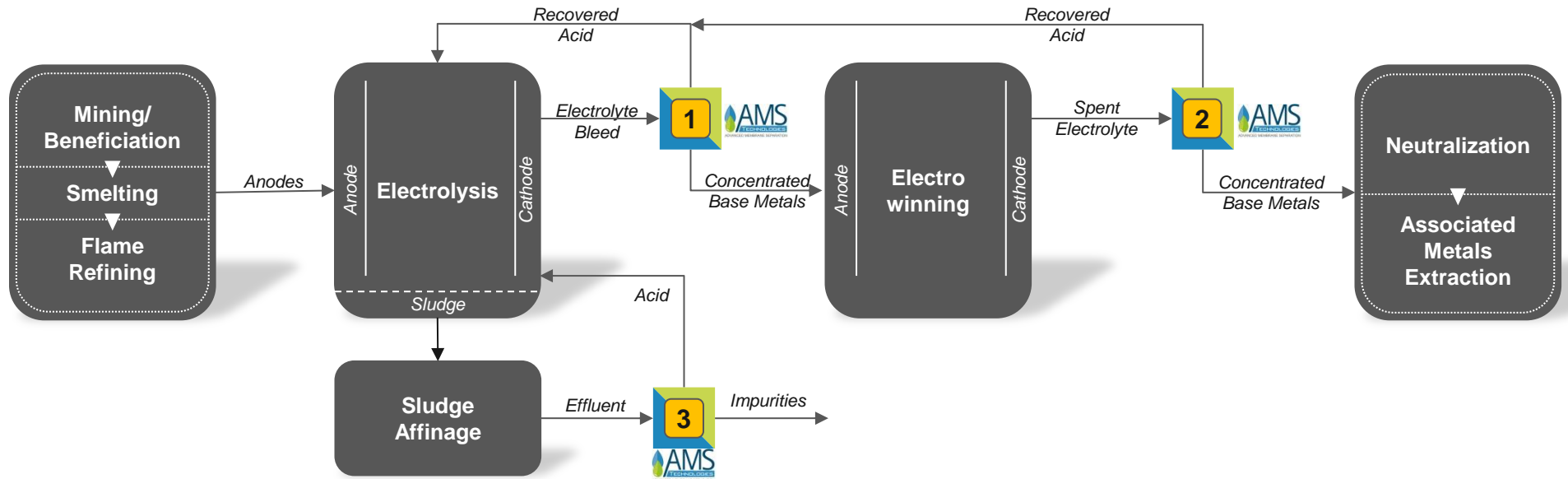


- Commercial scale 3 of 8-inch spiral wound elements;
- High-pressure part is made from Hastelloy (shown in blue), providing durability and stability for high acid concentrations

- ✓ **Pre-treatment stage** with 5 $\mu$  filters and own low-pressure pump;
- ✓ **Hastelloy high-pressure pump and pressure lines** for low pH operations;
- ✓ **Pilot-mode** option with one operating element;
- ✓ **Pressure relief** and cycling lines;
- ✓ **“Trucking” dimensions**: 3×3×2 m, 500 kg.

# High potential comes from using membrane technology in pyrometallurgical process

## Pyrometallurgical production process and membrane applications

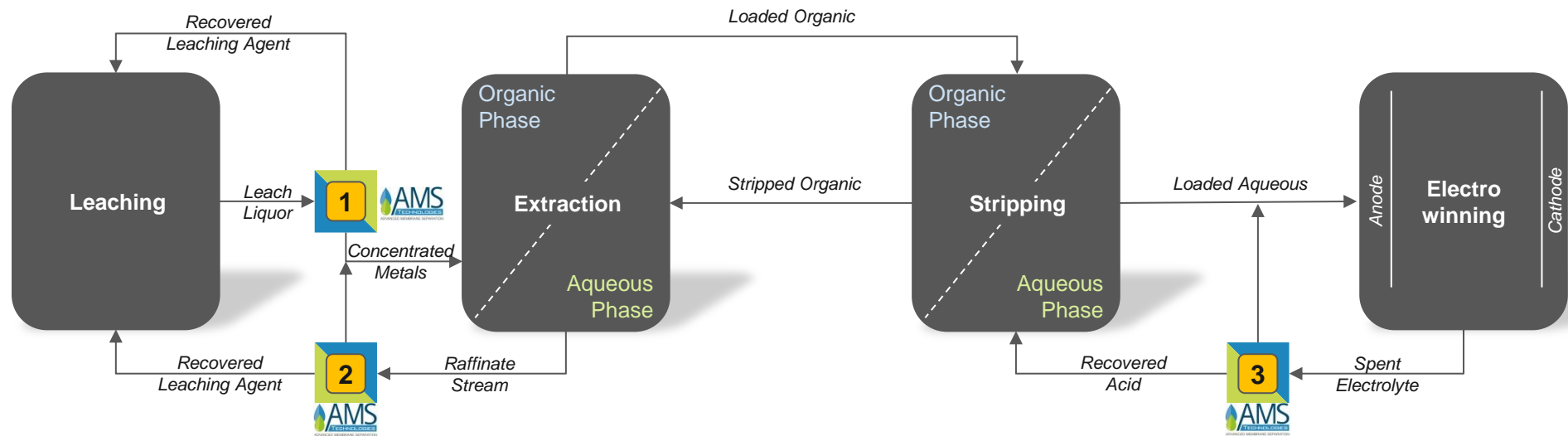


Treatment of	1 Spent Electrolyte	2 Regenerated Electrolyte	3 Affinage Effluent
Purposes	<ol style="list-style-type: none"> <li>1. Recover acid for re-use;</li> <li>2. Concentrate metal for electrowinning.</li> </ol>	<ol style="list-style-type: none"> <li>1. Recover acid for re-use;</li> <li>2. Concentrate associated base metals for extraction;</li> <li>3. Decrease neutralization expense.</li> </ol>	<ol style="list-style-type: none"> <li>1. Recover acid and associated precious metals (e.g. Au, Ag) for extraction.</li> </ol>
Filtrate	<ul style="list-style-type: none"> <li>• Clean acid as recovered electrolyte.</li> </ul>	<ul style="list-style-type: none"> <li>• Clean acid as recovered electrolyte.</li> </ul>	<ul style="list-style-type: none"> <li>• Clean acid</li> </ul>
Concentrate	<ul style="list-style-type: none"> <li>• Acid with increased metal concentration.</li> </ul>	<ul style="list-style-type: none"> <li>• Acid with increased metal concentration.</li> </ul>	<ul style="list-style-type: none"> <li>• Impurities for discharge</li> </ul>



# Several membrane applications were defined in Solvent Extraction & Electrowinning (SX/EW) process

## SX/EW production process and membrane applications



Treatment of	1 Leach Liquor	2 SX Raffinate	3 Spent Electrolyte
Purposes	<ol style="list-style-type: none"> <li>1. Concentrate metals for extraction;</li> <li>2. Recover leaching agent.</li> </ol>	<ol style="list-style-type: none"> <li>1. Purify leaching agent;</li> <li>2. Recover remaining metals for extraction.</li> </ol>	<ol style="list-style-type: none"> <li>1. Purify acid for stripping phase.</li> </ol>
Filtrate	<ul style="list-style-type: none"> <li>• Clean leaching agent.</li> </ul>	<ul style="list-style-type: none"> <li>• Clean leaching agent.</li> </ul>	<ul style="list-style-type: none"> <li>• Cleaned acid for re-use.</li> </ul>
Concentrate	<ul style="list-style-type: none"> <li>• Leaching agent with increased metals concentration.</li> </ul>	<ul style="list-style-type: none"> <li>• Leaching agent with increased metals concentration.</li> </ul>	<ul style="list-style-type: none"> <li>• Acid with increased metal concentration for EW.</li> </ul>

# Zinc from leach solution concentrated 3 times to improve evaporative crystallization

## African zinc miner uses low-MWCO membranes ...

<b>Client</b>	Zinc Producer
<b>Project Region</b>	Middle Africa
<b>Application</b>	NF treatment of leach solution
<b>Treatment Vol.</b>	Approx. 100 m <sup>3</sup> /day
<b>Design</b>	Single-pass with 100 Da NF membrane

## ... to reduce evaporator power consumption ...

<b>Feed Solution</b>	Zn:	25 g/L
<b>Treatment Highlights</b>	Zn:	3-times concentration increase with >99% mass recovery in concentrate
<b>Realized Benefits</b>	<ol style="list-style-type: none"> <li><b>Acid recovery</b> enables reuse, decreasing a) acid consumption, b) transportation and handling;</li> <li><b>Zinc concentration</b> allowed to reduce ~3 times the power consumption of evaporative crystallizer</li> </ol>	

## ... by concentrating zinc 3 times from 25 to 75 g/L

<i>mg / liter</i>	<b>Feed</b>	<b>Permeate</b>	<b>Concentrate</b>
<b>Volume</b>	100%	67%	33%
<b>Zn</b>	25 000	257	75 000
<b>Mg</b>	3 200	26	9 500
<b>Mn</b>	1 100	34	3 300
<b>Cu</b>	350	7.7	1 000
<b>pH</b>	3.7	3.7	3.7



# Electrolyte bleed of Cu-Co mine treated to recover 63% of clean acid and increase concentrate metals

## African Cu-Co mine employs NF membranes ...

<b>Client</b>	Copper-cobalt Mine
<b>Project Region</b>	Middle Africa
<b>Application</b>	NF treatment of electrolyte bleed
<b>Treatment Vol.</b>	Approx. 100 m <sup>3</sup> /day
<b>Design</b>	Single-pass with 100 Da NF membrane

## ... to recover clean acid and improve precipitation ...

<b>Feed Solution</b>	<b>H<sub>2</sub>SO<sub>4</sub></b>	18 g/L
	<b>Co:</b>	330 mg/L
<b>Treatment Highlights</b>	<b>H<sub>2</sub>SO<sub>4</sub></b>	17 g/L in permeate with 63% recovery
	<b>Co:</b>	960 mg/L in conc. with 99% recovery
<b>Realized Benefits</b>	<ol style="list-style-type: none"> <li><b>Acid recovery</b> enables reuse, decreasing a) acid consumption, b) transportation and handling;</li> <li><b>Cobalt concentration</b> increased ~3 times improving precipitation efficiency and reagent consumption</li> </ol>	

## ... by concentrating cobalt 3 times from 330 to 960 mg/L

<i>mg / liter</i>	<b>Feed</b>	<b>Permeate</b>	<b>Concentrate</b>
<b>Volume</b>	100%	67%	33%
<b>H<sub>2</sub>SO<sub>4</sub></b>	18 000	17 000	21 000
<b>Co</b>	330	12	960
<b>Cu</b>	2 300	34	6 900
<b>Fe</b>	700	13	2 100
<b>Mg</b>	15 000	700	45 000