CHIMERICAL TECHNOLOGY

Membrane Technology Advances for Base Metal Processes using AMS Technologies

- ✓ 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

Visit our website www.ChimericalTech.com for more information on our solutions

Nanofiltration Membranes

Low-MWCO NF Membranes

Low-MWCO NF Membranes in Base-metals

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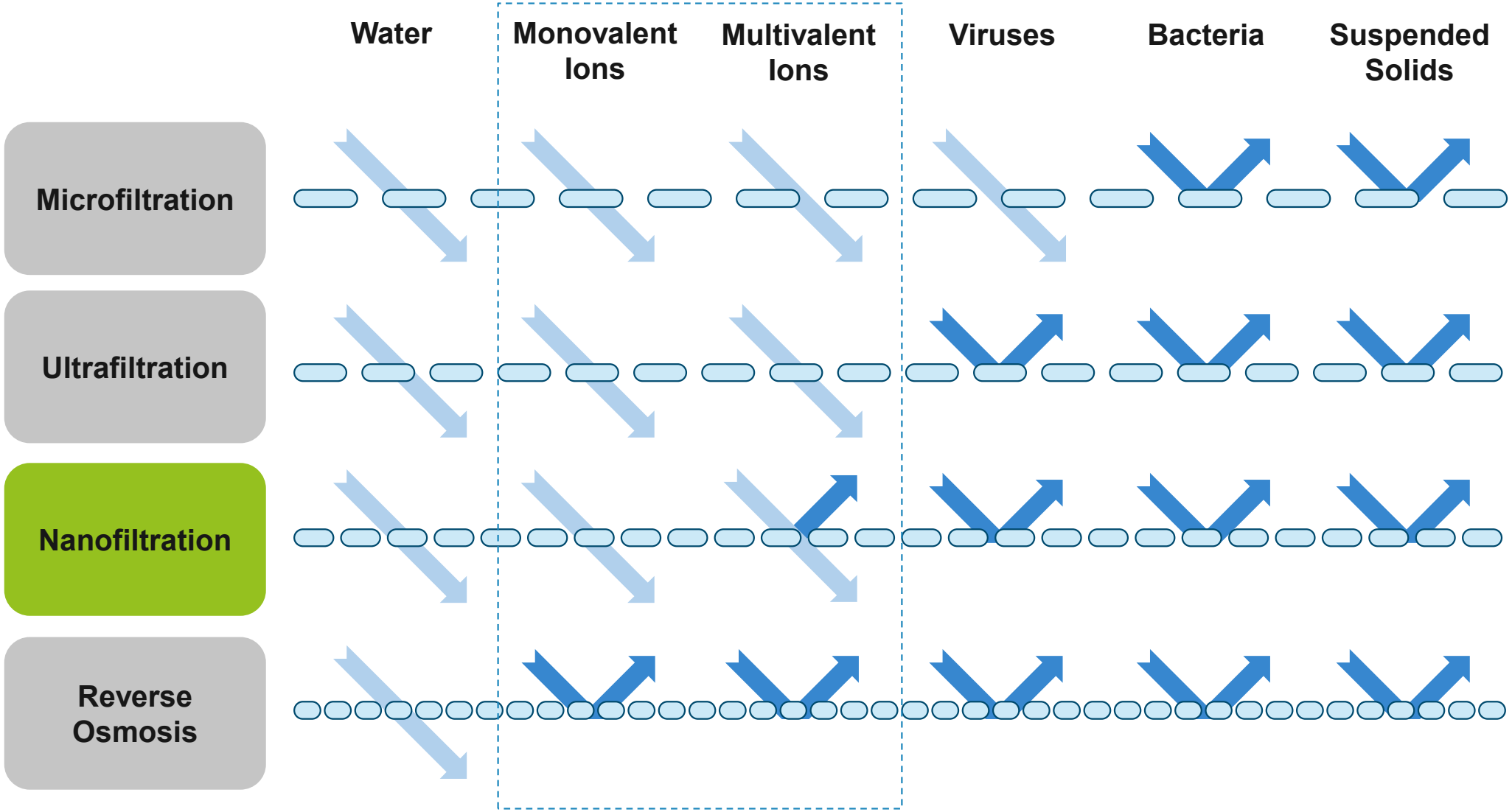
Nanofiltration (NF) membranes have rejection selectivity: allowing components based on size and charge



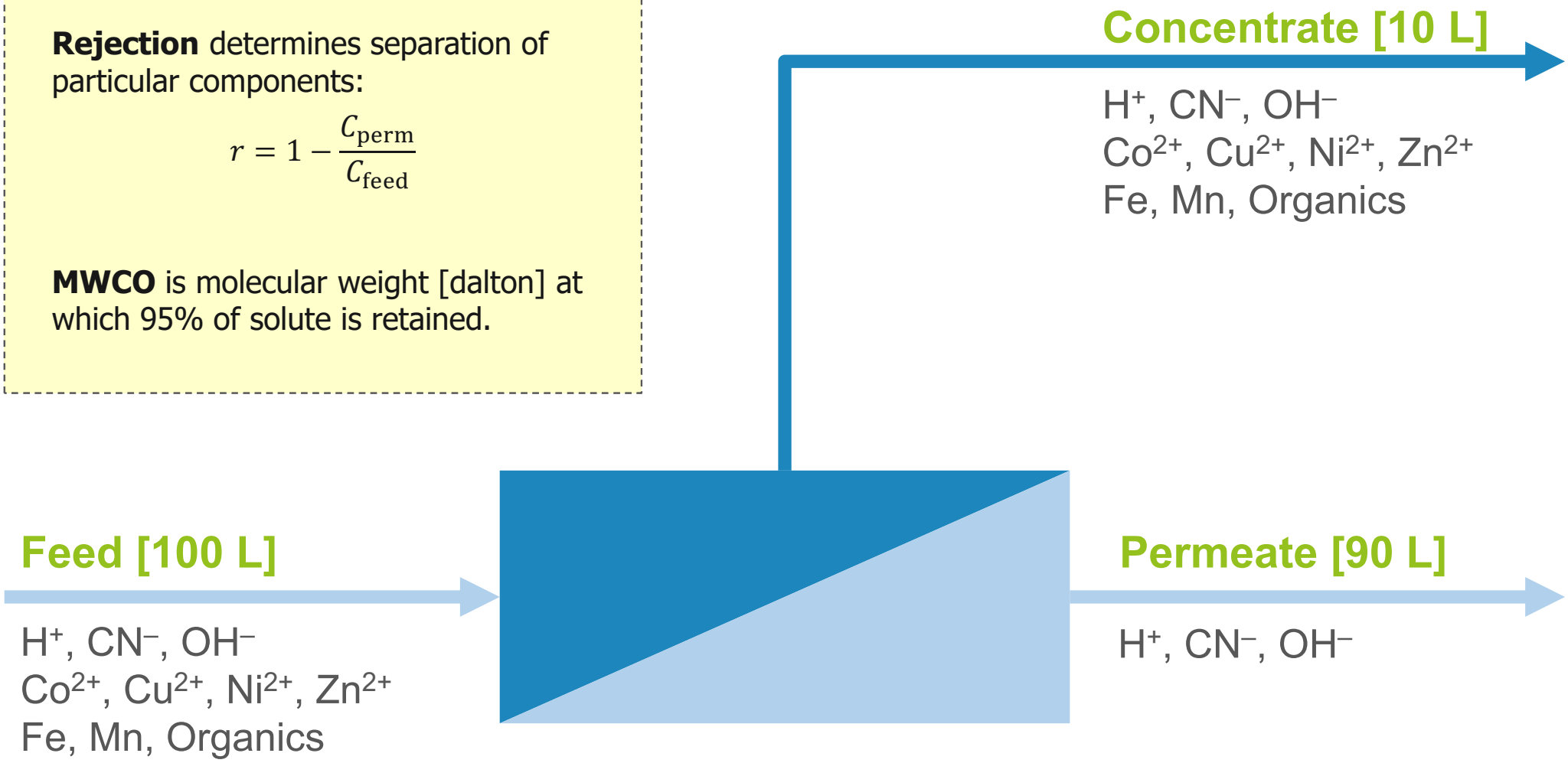
Source: AMS Technologies

Charge-based NF separation lies in the heart of reagent recovery and metal concentration applications

Rejection determines separation of particular components:

$$r = 1 - \frac{C_{\text{perm}}}{C_{\text{feed}}}$$

MWCO is molecular weight [dalton] at which 95% of solute is retained.



Source: AMS Technologies

Nanofiltration Membranes

Low-MWCO NF Membranes

Low-MWCO NF Membranes in Base-metals

Nanofiltration Membranes in Base-metals

Low-MWCO membrane is a new product for ultra-pure reagent recovery and no-loss metal concentration

MWCO and rejection = how “strict” is the membrane in stopping components:

- Low MWCO (High rejection) = Hard to escape from concentrate side;
- High MWCO (Low rejection) = Easy to reach permeate side.

		400 Da		200 Da		100 Da	
	Feed	Conc.	Perm.	Conc.	Perm.	Conc.	Perm.
Volume	**100**	**20**	**80**	**20**	**80**	**20**	**80**
Concentration							
H_2SO_4	10	10.2	10.0	10.8	9.8	11.7	9.6
$CuSO_4$	10	44.0	1.5	46.9	0.8	49.6	0.1
Mass							
H_2SO_4	100%	20%	80%	22%	78%	23%	77%
$CuSO_4$	100%	88%	12%	94%	6%	99%	1%

Source: AMS Technologies

Mining and Metals industry impose high stability requirements on membrane

Superior pH stability is mandatory — streams often have high acid, alkali, solvents …

Stability	Membrane	MWCO[1], daltons	Min. $MgSO_4$ Rejection[2]	pH range	Example Streams
Acid	A–3011	100	99%	0 — 12	
	A–3012	180	96%	0 — 12	20% H_2SO_4
	A–3014	400	92%	0 — 12	20% HCl
	A–3017	700	80%	0 — 12	30% H_3PO_4
	A–3020	1′000	65%	0 — 12	
Base	B–4021	100	99%	3 — 14	
	B–4022	180	96%	3 — 14	20% NaOH
	B–4027	700	80%	3 — 14	20% KOH
	B–4030	1′000	65%	3 — 14	
Solvent	S–3011	100	99%	2 — 12	MeOH,
	S–3012	180	96%	2 — 12	Acetone,
	S–3014	400	92%	2 — 12	DMF, etc.

… as well as thermal and pressure stability

Thermal durability

- ✓ No need for cooling;
- ✓ Higher flux;
- ✓ up to 80°C (176 °F).

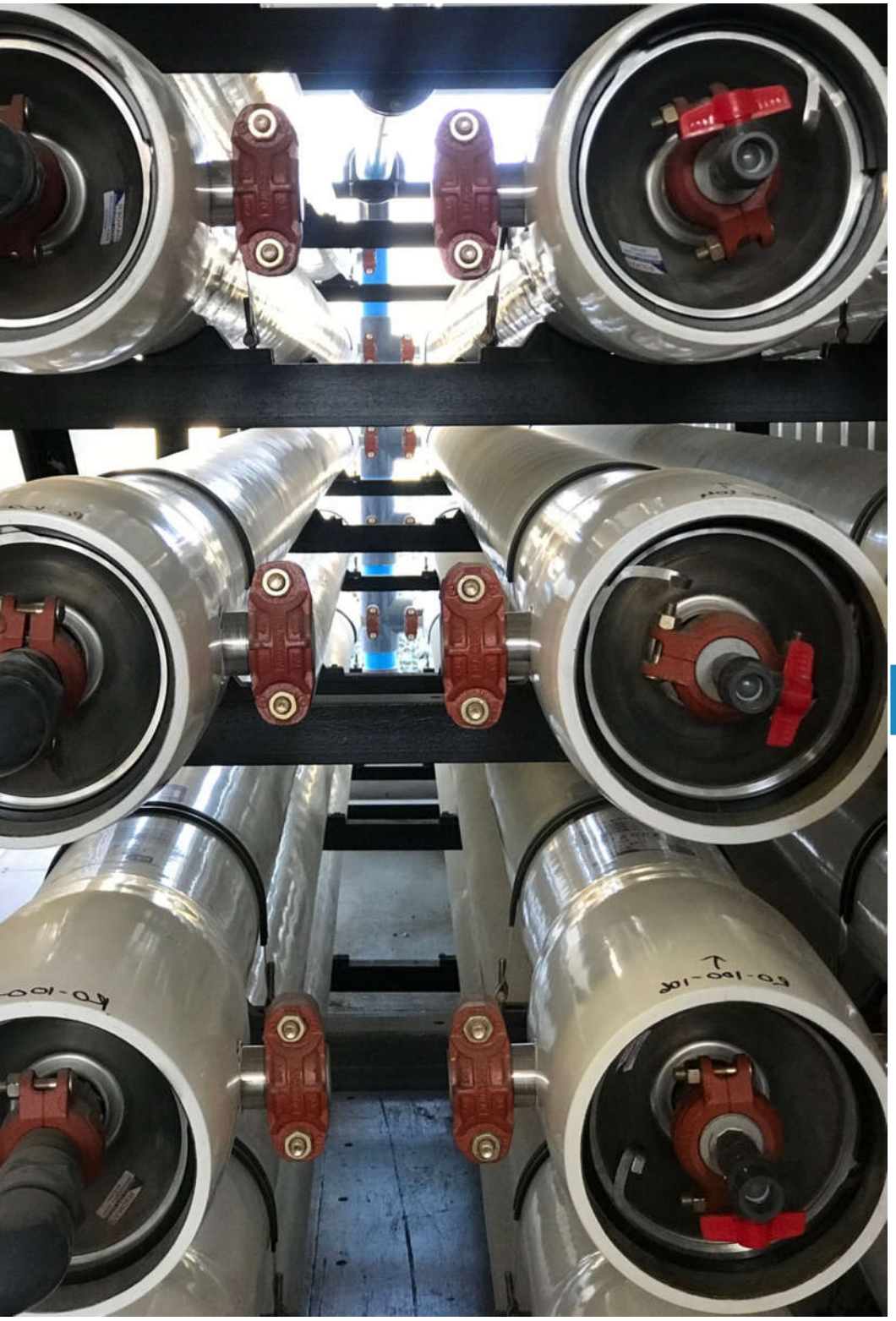
Pressure durability

- ✓ Better recovery at high osmotic pressure conditions;
- ✓ Higher flux;
- ✓ AMS up to 70 bar.

Differential pressure stability:

- ✓ Can treat viscous streams;
- ✓ Higher flexibility in system design;
- ✓ AMS' up to 1 bar.

1. MWCO = Molecular Weight Cut-Off, the lowest molecular weight solute (in daltons, 1 dalton = 1 g/mol) in which 95% of the solute is retained by the membrane; 2. Conditions: 0.2% $MgSO_4$ solution, 40 bar, 30°C
Source: AMS Technologies



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Zinc from leach solution concentrated 3 times to improve evaporative crystallization

African zinc miner uses low-MWCO membranes …

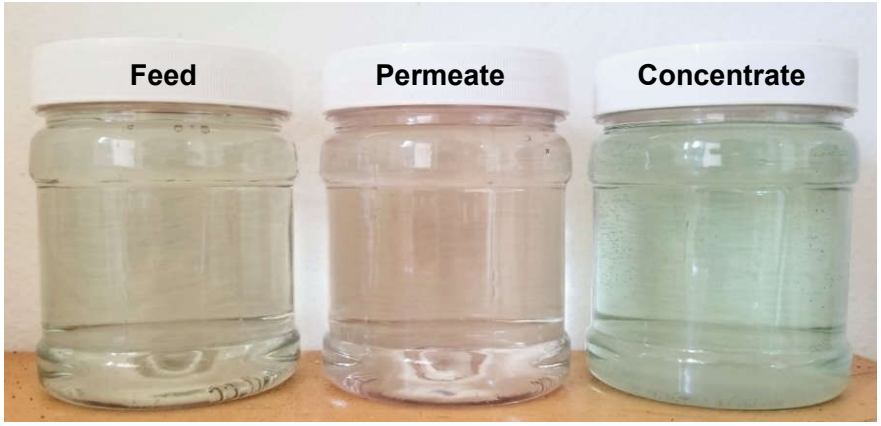
Client	Zinc Producer
Project Region	Middle Africa
Application	NF treatment of leach solution
Treatment Vol.	Approx. 100 m^3/day
Design	Single-pass with 100 Da NF membrane

… to reduce evaporator power consumption …

Feed Solution	**Zn:**	25 g/L
Treatment Highlights	**Zn:**	3-times concentration increase with >99% mass recovery in concentrate
Realized Benefits	1. **Acid recovery** enables reuse, decreasing *a)* acid consumption, *b)* transportation and handling; 2. **Zinc concentration** allowed to reduce ~3 times the power consumption of evaporative crystallizer	

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

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



Source: AMS Technologies; Chimerical Technology

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

African Cu-Co mine employs NF membranes …

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

… to recover clean acid and improve precipitation …

Feed Solution	**H_2SO_4** **Co:**	18 g/L 330 mg/L
Treatment Highlights	**H_2SO_4** **Co:**	17 g/L in permeate with 63% recovery 960 mg/L in conc. with 99% recovery
Realized Benefits	1. **Acid recovery** enables reuse, decreasing *a)* acid consumption, *b)* transportation and handling; 2. **Cobalt concentration** increased ~3 times improving precipitation efficiency and reagent consumption	

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

mg / L	**Feed**	**Permeate**	**Concentrate**
Volume	100%	67%	33%
H_2SO_4	18 000	17 000	21 000
Co	330	12	960
Cu	2 300	34	6 900
Fe	700	13	2 100
Mg	15 000	700	45 000

High $MgSO_4$ content caps the recovery

Source: AMS Technologies; Chimerical Technology

Multi-pass design can achieve ultra-high purity of recovered reagents

Process developed to recover acid from spent copper electrolyte

- Client is large vertically integrated Cu producer in Eastern Europe;
- Spent copper electrolyte is rich in Ni and Cu;
- Acid to be purified to **< 50 ppm** to enable re-use.

Treatment designed around 3 passes consequently treating permeates

- **UF:** Removes any remaining TSS, securing NF elements. Conditioning for NF;
- **NF-1:** 400 Da membrane at high recovery removing most of impurities;
- **NF-2:** 100 Da membrane is polishing recovered acid to required purity.

As a result, impurities reduced to < 50 ppm level

- 63% of acid recovered with impurities reduced from 8.2 g/L to **29 ppm** (*~log3*);
- $NiSO_4$ up to 25 g/L in conc. for richer cake.

mg / L		UF	NF-1	NF-2	NF1+NF2
	Feed	Perm.	Perm.	Perm.	Conc.
Volume	**100%**	**90%**	**72%**	**65%**	**25%**
Concentration					
H_2SO_4	170′000	170′000	170′000	160′000	181′000
Cu	670	616	115	8	2′179
Ni	7′500	7′001	806	20	25′000
Fe	74	68	10	1	243
Mass					
H_2SO_4	100%	90%	72%	63%	27%
Cu	100%	83%	12%	< 0.5%	83%
Ni	100%	84%	8%	< 0.5%	84%
Fe	100%	84%	10%	< 0.5%	83%

Source: AMS Technologies

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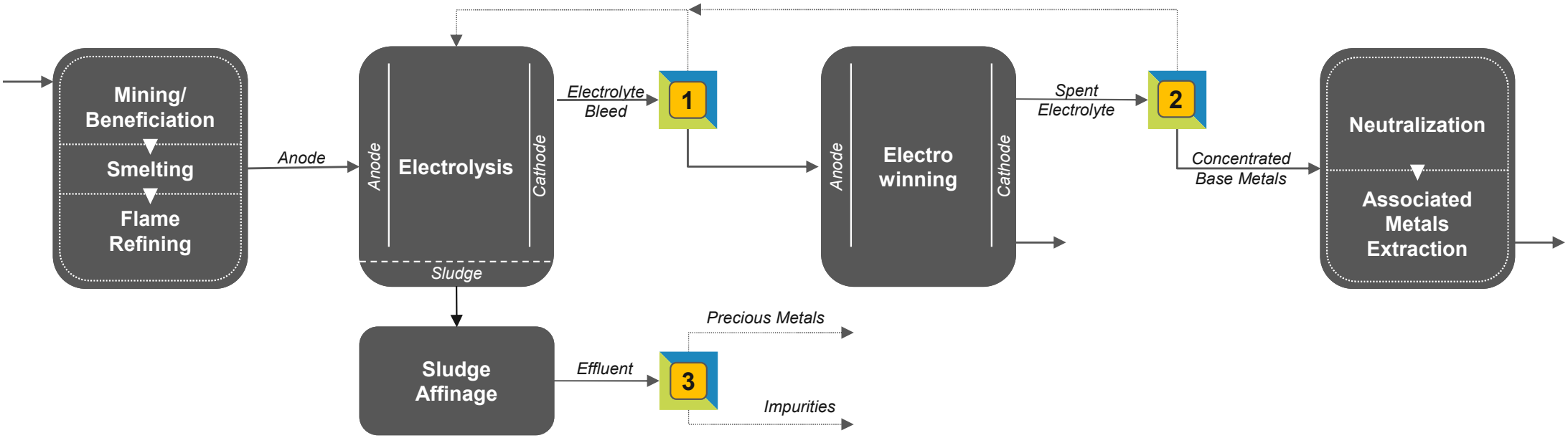
High potential comes from using membrane technology in pyrometallurgical process

Pyrometallurgical production process and membrane applications

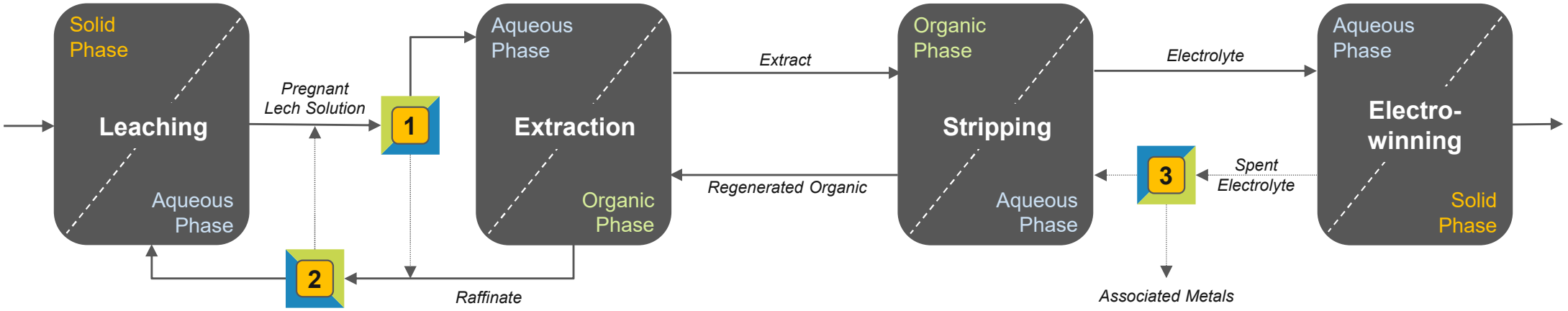


Treatment of	1 Spent Electrolyte	2 EW Spent Electrolyte	3 Affinage Effluent
Purposes	1. Recover acid for re-use; 2. Concentrate metal for electrowinning.	1. Recover acid for re-use; 2. Concentrate associated base metals for extraction; 3. Decrease neutralization expense.	1. Recover acid and associated precious metals (e.g. Au, Ag) for extraction.
Filtrate	• Clean acid as recovered electrolyte.	• Clean acid as recovered electrolyte.	• Clean acid
Concentrate	• Acid with increased metal concentration.	• Acid with increased metal concentration.	• Impurities for discharge

Source: AMS Technologies

Three potential membrane applications are found in SX/EW circuit

SX/EW production process and membrane applications



Application	1 PLS Upgrade	2 Raffinate Purification	3 Electrolyte Regeneration
Purposes	1. Increase metal concentration to facilitate extraction	1. Purify leaching agent (e.g. decrease viscosity for better leaching); 2. Prevent metal loss.	1. Purify acid for re-use in stripping phase; 2. Collect associated metals.
Filtrate	• Purified agent for re-use in leaching	• Purified agent for re-use in leaching	• Purified acid for re-use in electrolysis
Concentrate	• Upgraded PLS	• PLS-like solution	• Concentrated associated metals (e.g. by-products)

Source: AMS Technologies