

INAP
WATER TREATMENT WORKSHOP
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Engineered Membrane Systems (EMS®) for
ARD & other Hydrometallurgical Applications

By Larry A. Lien
Director, Membrane Technology
HW Process Technologies, Inc.

Why Membrane Technology?

The mining and metals refinery industry can benefit from membrane technology:

- Recovery of metals
- Recovery of acids or caustic
- Recovery of energy
- Reduction of disposal costs
- Meet Discharge limits currently not attainable with traditional chemical precipitation

Membrane Classification

Microfiltration (MF)	.1 to 1 micron	Bacteria
Ultrafiltration (UF)	6K to 100K MWCO	Proteins
Thin Film UF	500, 1K, 2K & 3K MWCO	Rejects Ferric Iron, Dyes & Small Colloids
Nanofiltration (NF)	150 to 500 MWCO	Divalent salts rejected 99% but transmits salts or acids
Hyperfiltration (HF)	50 to 150 MWCO	Rejects all salts and acids 99+%

Membrane-elements

Membrane Types

- Polysulfone – 3 types
- PVDF
- PAN
- Modified PAN
- Cellulose Acetates – CA, UF, NF, HF
- Thin-film composite UF, NF, HF of polyamides, sulfonated polysulfones, and proprietary polymers

Typical Spiral-wound Elements

- Typical construction: 20 cm x 100 cm (30 m²)
- High temperature – 140 °C
- High pH – 14
- Low pH – 0
- High viscosity – 300 Centipoise @ 90 °C
- High solids (soluble and suspended)
- Ultra-high pressures – 200 Bar

Acid reclamation concentration with HF or purification with NF

- Sulfuric
- Nitric
- Hydrochloric
- Hydrofluoric
- Boric
- Phosphoric
- Acetic
- Citric

Caustic high-pH environments with special HF and NF membranes

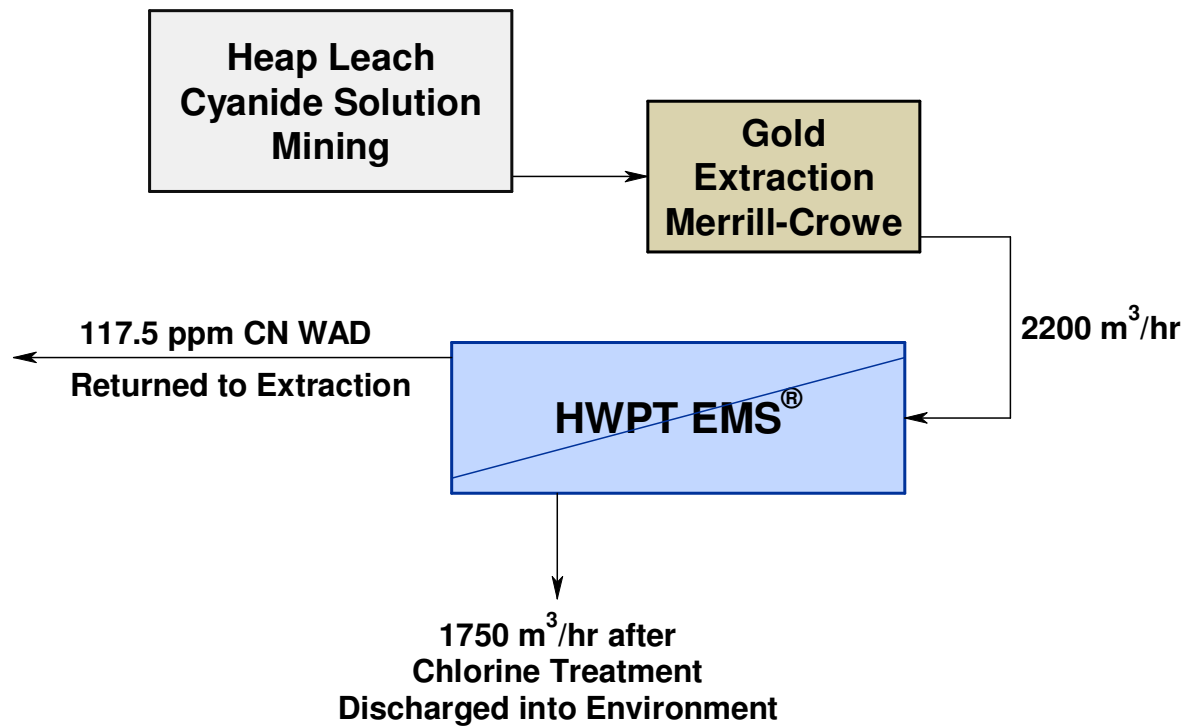
- Operated HF in high-pH cyanide solutions for 4 years' special construction to meet HWPT processing needs
- Recovery of 5% caustic solution with NF membrane with special construction for HWPT processes

Yanacochoa

- Gold mining heap leach water balance issue at Yanacochoa, Peru
- First HW Process Technologies Engineered Membrane Separation[®] (EMS[®]) system installed in 2003
- Currently, 2750 m³/hr of barren leach solution is treated and discharged safely into the environment
- Original elements installed in 2003 still operating effectively



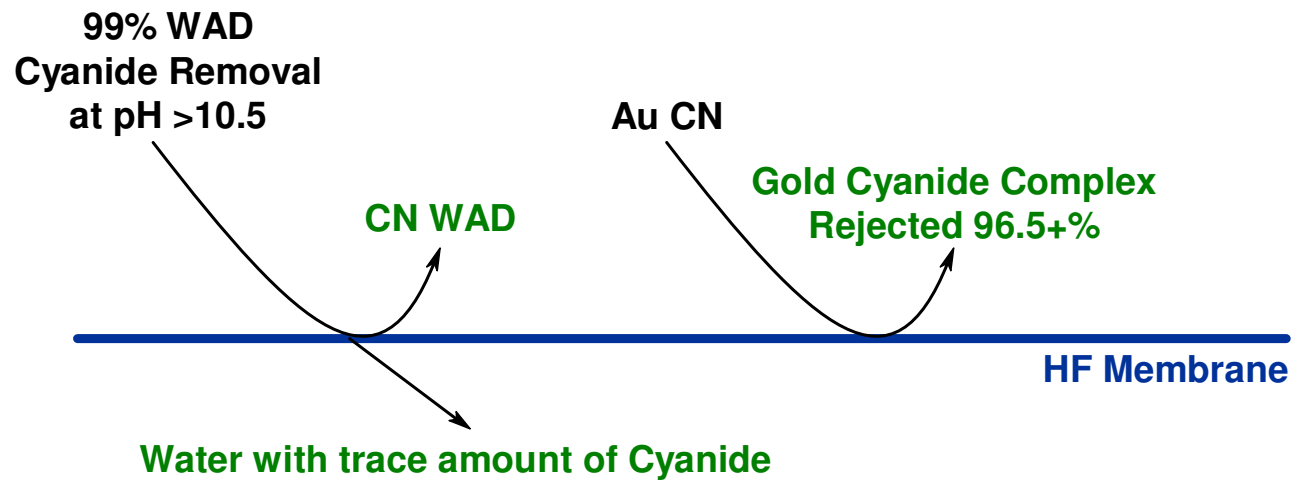
Yanacocha process overview



Water quality at Yanacocha

Ion mg/L	Feed mg/L	Permeate mg/L	Concentrate mg/L	Discharge Limit mg/L
pH	10.1	8.0	9.7	6.0–9.0
CN WAD	46.7	<.05	117.5	0.2
Arsenic	0.4	<.01	1.5	0.5–1.0
Mercury	0.0025	<.0005	0.0076	0.002
Nitrite	5.19	0.09	17.11	
Nitrate	27.5	0.64	89.8	
Copper	3.1	0.1	11.6	0.3
Zinc	17.2	0.3	65.1	1

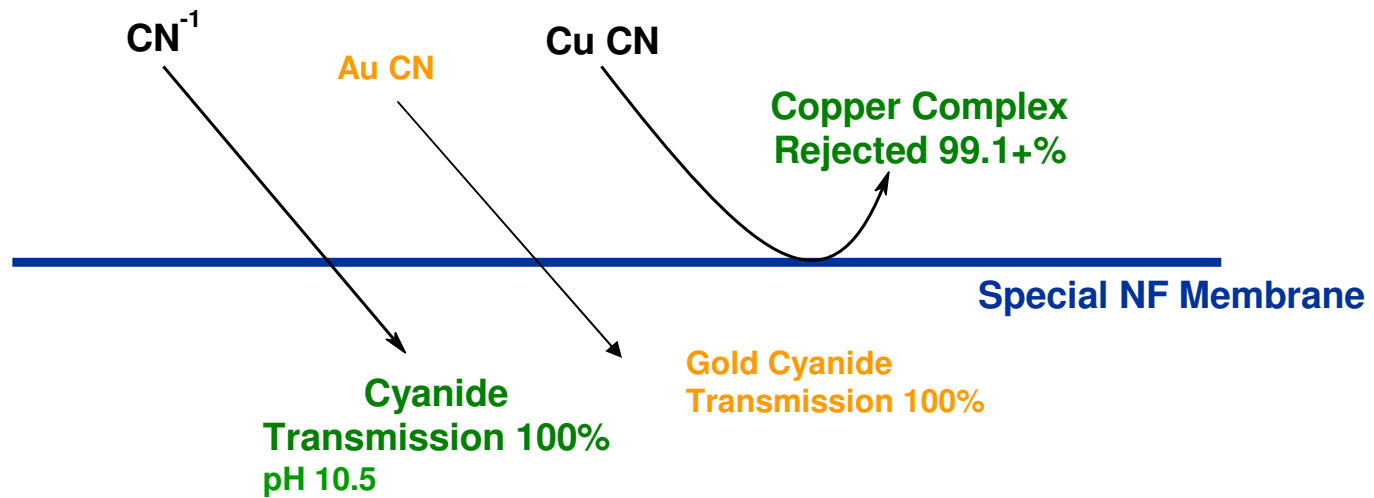
HF of gold-cyanide complex concentration



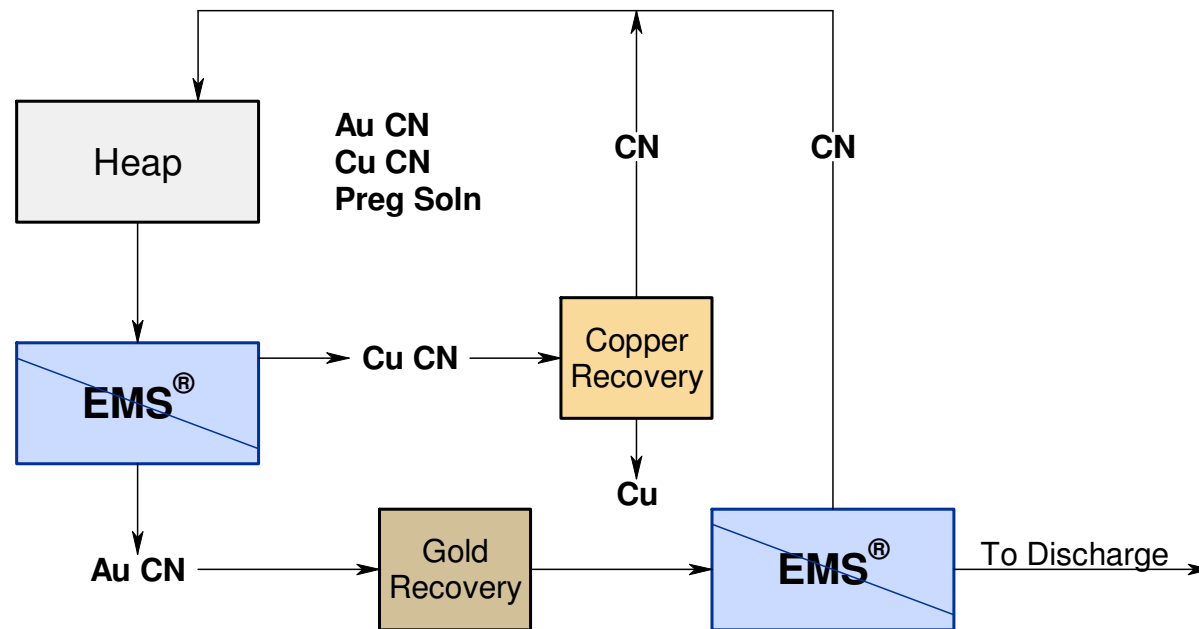
Comments from Newmont's Operators

- Meets water quality discharge standards (*including nitrites and nitrates not regulated*)
- Allows for future safe operation and expansion
- Increased Gold and Silver recovery in membrane concentrates (*Au and Ag rejected at 96.5% rate by membranes – especially important during upset conditions*)
- Cyanide recovery for re-use
- Chlorine consumption reduced by 75% and overall operating cost 70% less than conventional precipitation plant
- EASY TO OPERATE

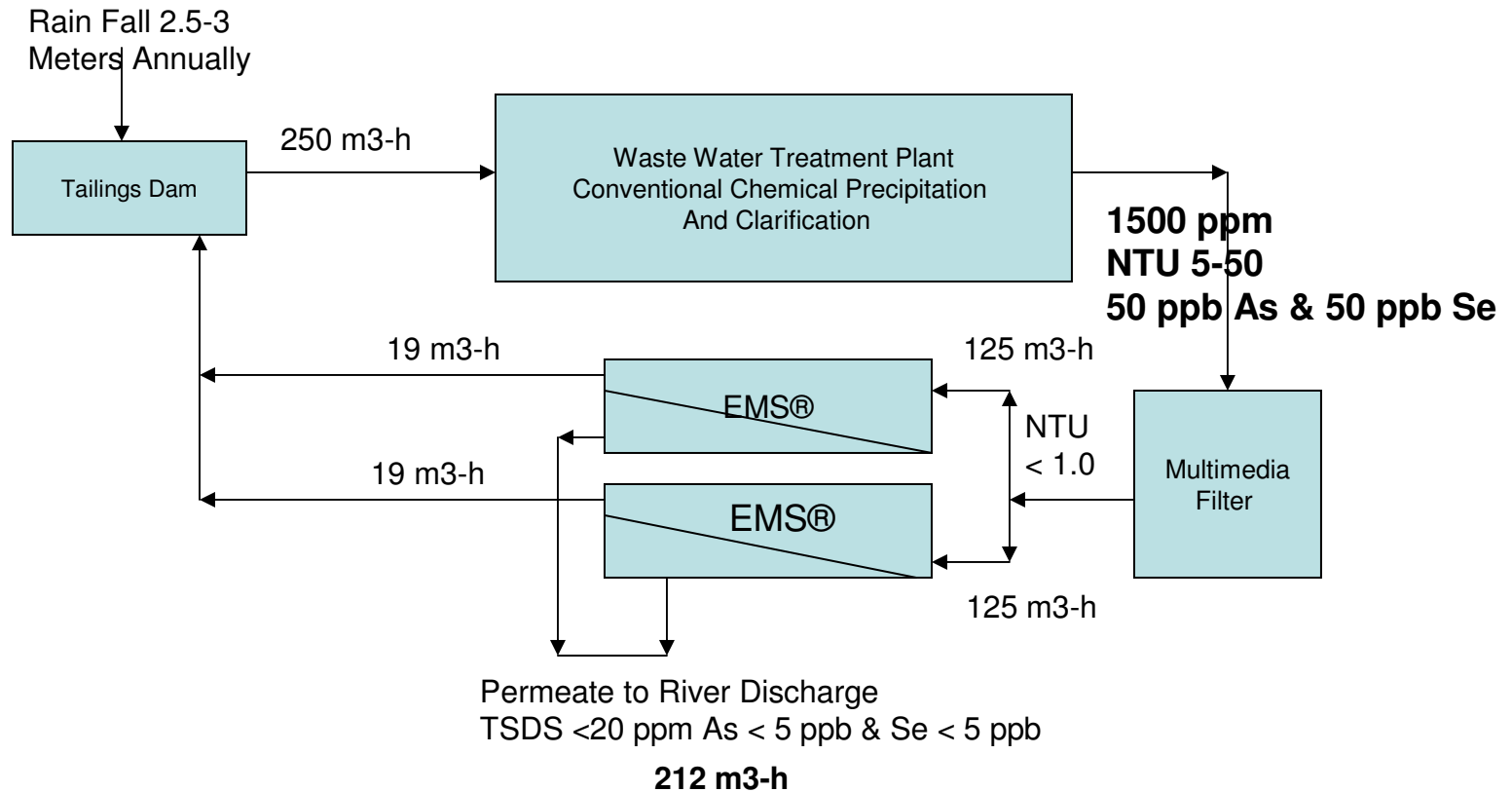
NF of Copper-Cyanide complex concentration



Copper-Gold Fractionation Process



Waihi Gold New Zealand Membrane Treatment Post Chemical Water Treatment Arsenic & Selenium Removal Process

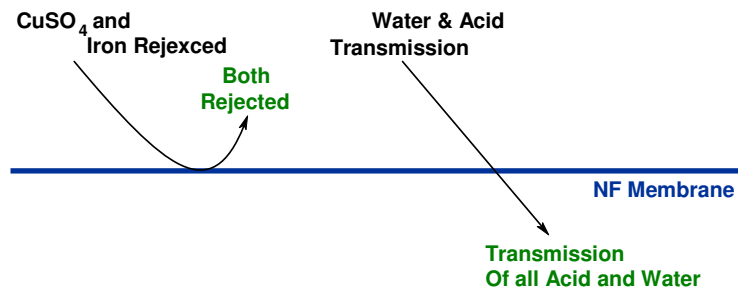


Water Quality Analysis from Waihi Gold

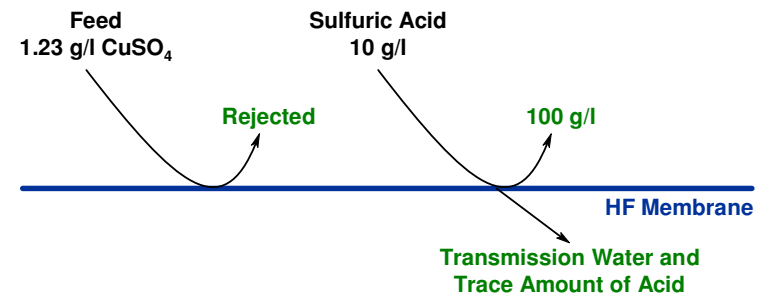
Ion mg/L	Feed mg/L	Permeate mg/L	Concentrate mg/L	Discharge Limit mg/L
pH	9.81	10.2	9.2	6.0–9.0
Calcium	340	<1.1	1500	NA
Antimony	0.36	<.007	2.7	< 0.025
Mercury	0.0015	<.0005	0.0076	0.002
Selenium	0.11	<.00022	.73	0.025
Cobalt	0.37	<.004	2.1	NA
Sulfate	1025	<2	5589	2000
Molybdenum	0.053	<.004	.50	NA

Use of special HF & NF Membrane-Elements

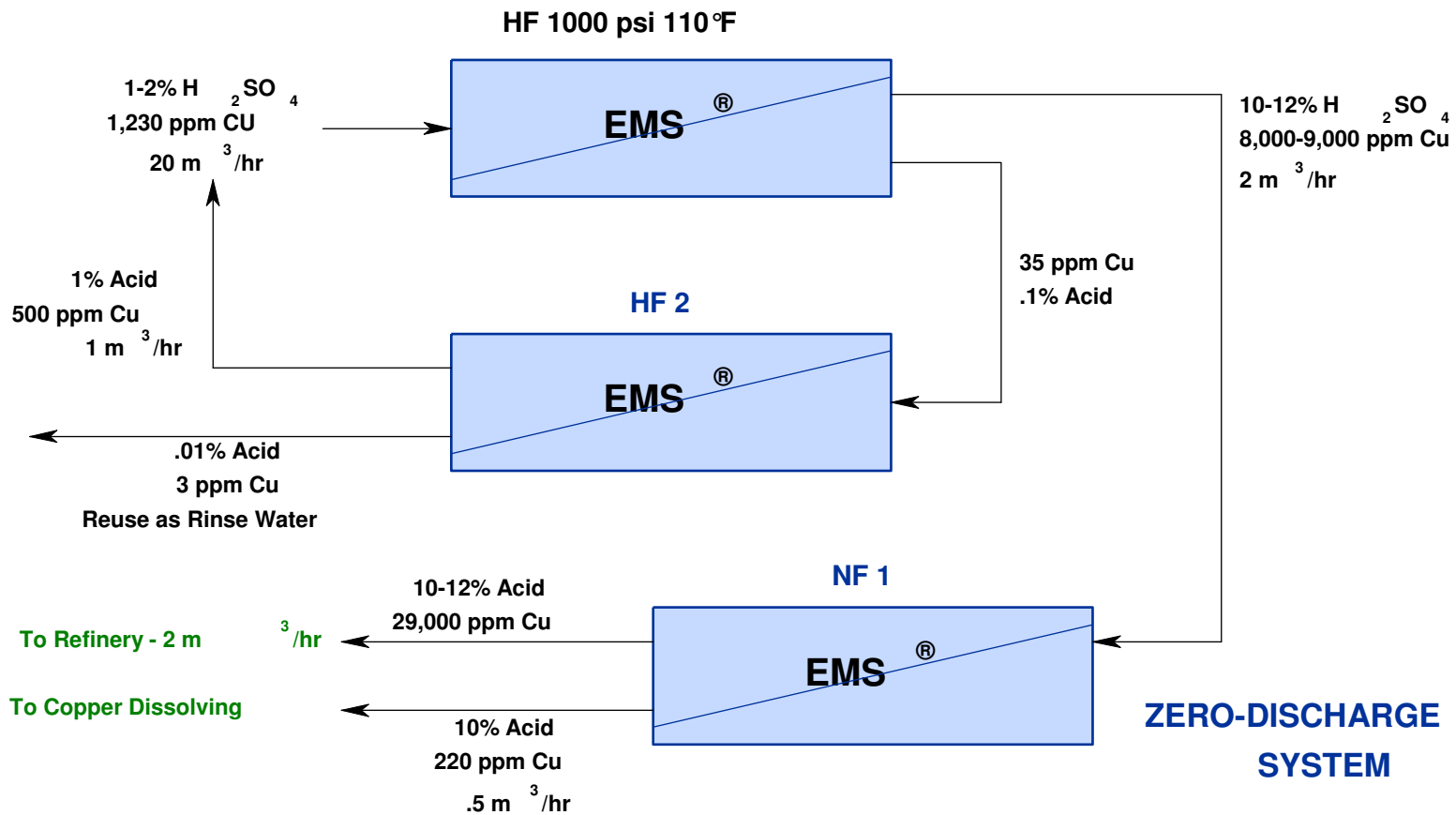
- NF Copper rejected & sulfuric acid transmission at Phelps-Dodge



- HF Copper and acid rejection at Phelps-Dodge

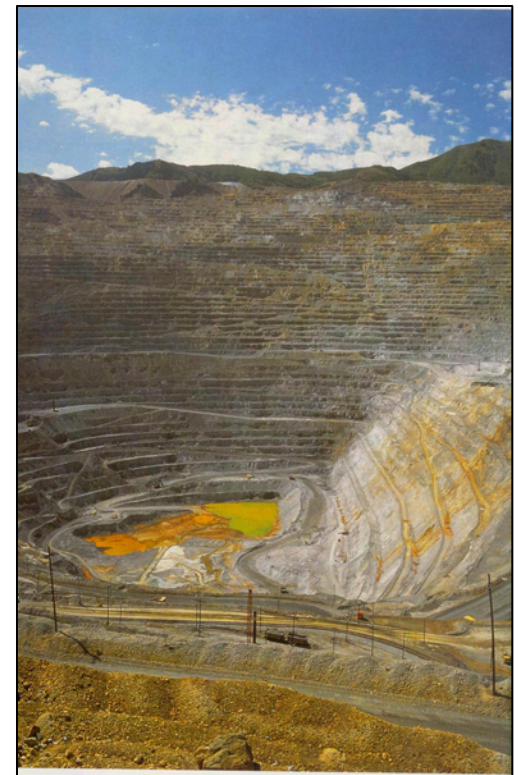
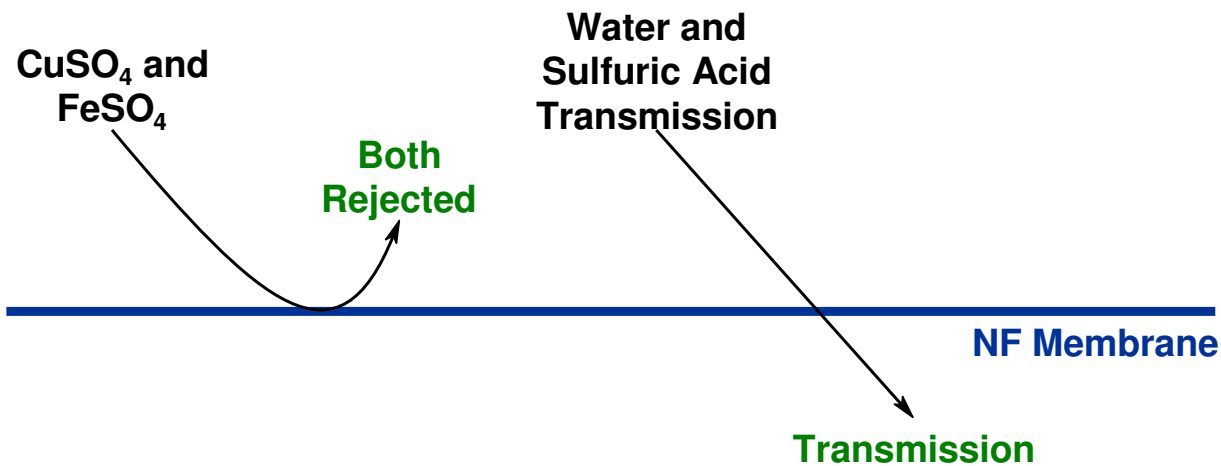


Zero Liquid Discharge 17 years Operation (Freeport McMoran) Phelps-Dodge Rod Mill El Paso, Tx

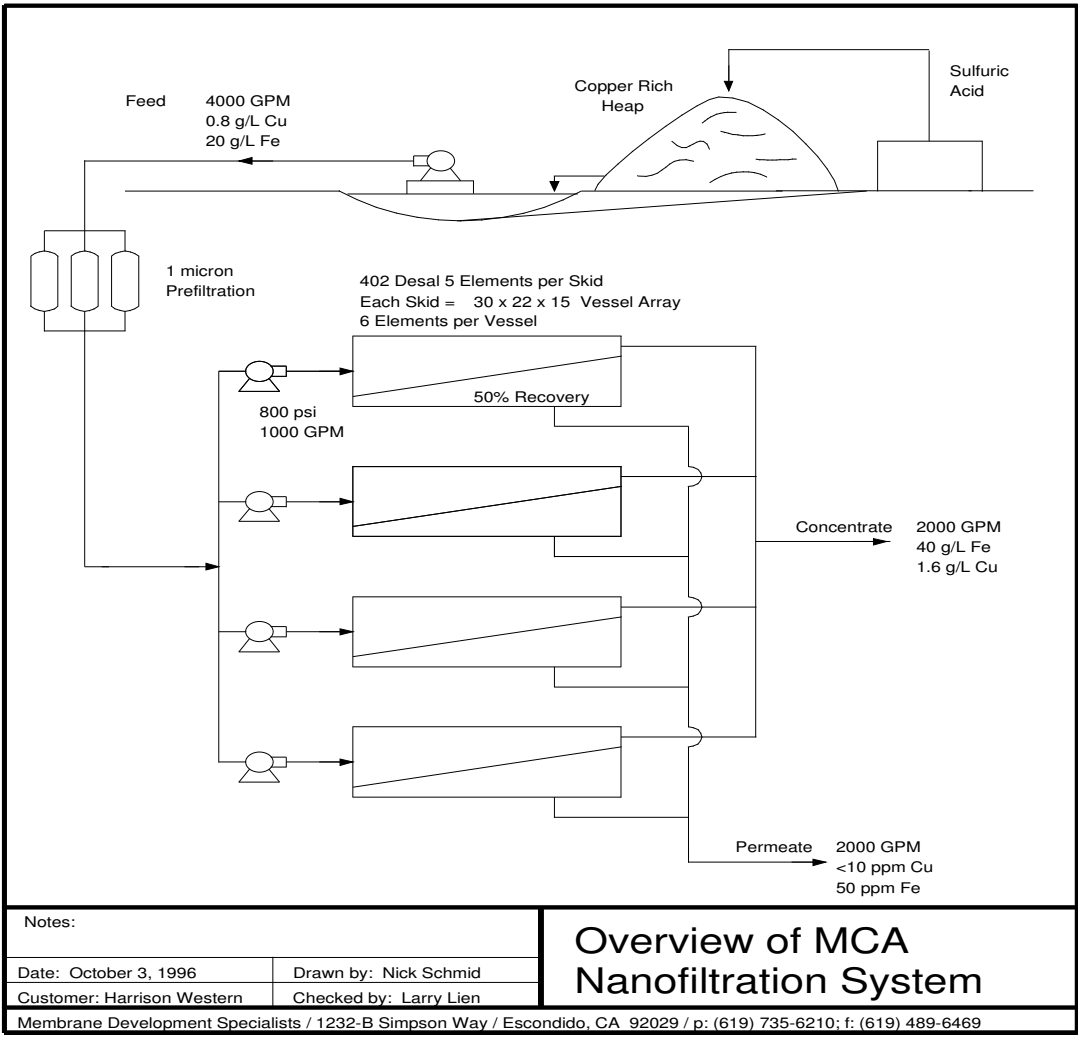


Cananea de Mexican Copper and Iron rejection

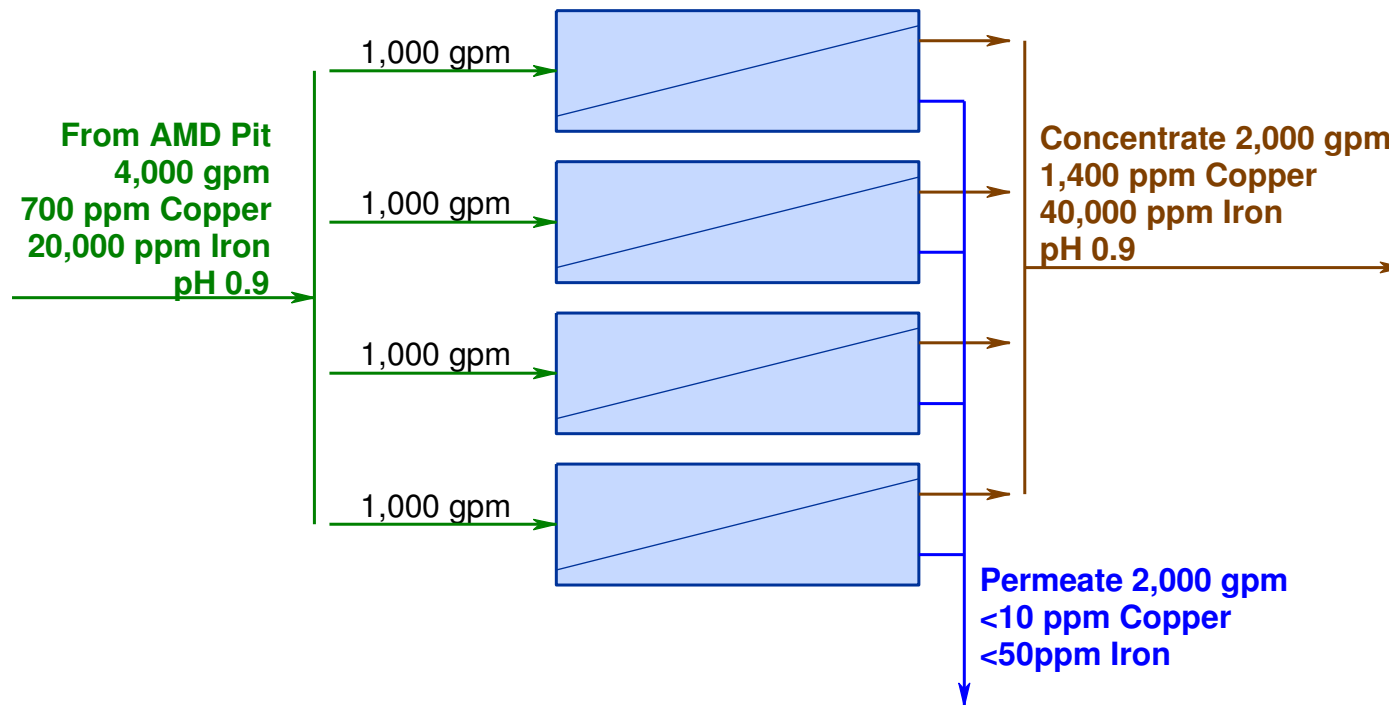
With special NF membrane-elements



AMD Copper Reclamation Process



AMD Copper Recovery Process



AMD Application at Cananea de Mexicana

- Recovery of copper directly from EMS[®] concentrate
- EMS[®] process paid for itself within 6 months via copper recovery
- Allowed mine to open new reserves that would previously have been flooded via an old 1890s mine shaft

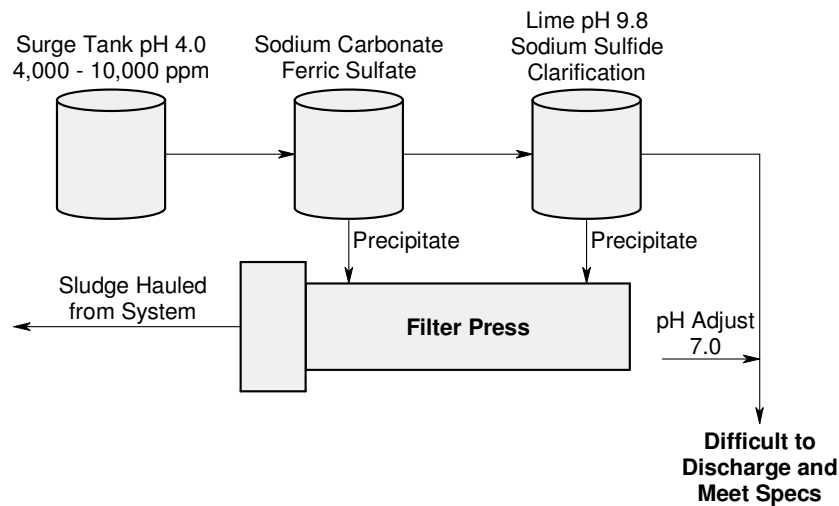


Asarco Refinery Wastewater Reclamation Project

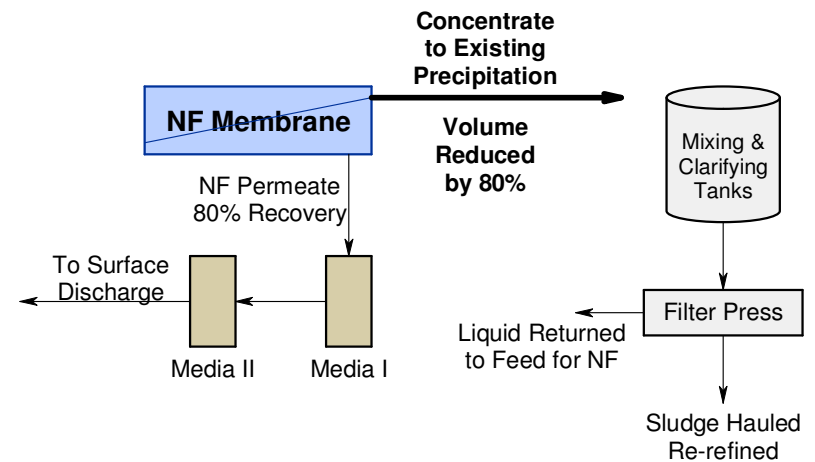
- Legacy refinery with ground water pollution issues after 100 years of operation
- Precipitation system installed in 1985 – \$1M capital and huge operating costs
- Membrane system installed in 1993 prior to precipitation – reduced volume to precipitation system from 6 m³/hr to 1 m³/hr

Comparison of Refinery Processes

- Copper refinery precipitation process prior to addition of membrane system



- Refinery layout with membrane system followed by precipitation



Capital and operating costs: Precipitation vs. Membrane-Media

	Precipitation	Membrane-Media
Cap Cost	\$1M	\$300K
Chemicals	\$2.61 per m ³	\$.15 *
Sludge disposal per m ³	\$26.53	\$1.35
Total sludge generated per m ³	19.24 Kg	2.88 Kg
Total Op cost per m ³ treated	\$29.15	\$1.82

** Membrane cleaning and media regeneration*

Final permeate water analyses

	Feed mg/l	Permeate mg/l
As	10.1	.081
Cd	14.5	.05
Zn	33.5	.01
Pb	3.07	.05
Cu	.073	.01
Fe	.986	.10
Mn	3.33	.05
Total Metals	67.9	.583
		99.14% Extraction

What makes EMS[®] plants unique?

- **Every Application is Pilot Tested on Site**
- **Special membranes and element construction for High and Low pH Applications**
- **Special system design for High and Low pH Applications**
- **Special operating procedures based on intimate knowledge of the client's process**
- **Special cleaning procedures**
- **20 years of process membrane systems experience**