SHORT COURSE

Copper SX/EW Basic Principles and Detailed Plant Design

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NCHANGA, ZAMBIA,1973
FIRST LARGE-SCALE COPPER SX-EW PLANT

Notes:

1. Processed 12,000 IGPM (3,264 m/hr) of solution from a tailings leach system in 4 parallel SX trains comprising 4 extraction and 2 stripping stages of conventional mixer-settlers.
2. The SX trains were the world's largest at the time. The combination of the required 3 minutes retention time in the extraction units and the single stage design resulted in "dead spots" in the mix boxes. This led to the later adoption of two or more mix boxes in series.
3. The mixer-settlers were constructed from pre-cast concrete, lined with very thin stainless steel. (which had to be installed at night to avoid expansion problems in hot sun.). Originally it was planned to use lead lining, but lead suffered corrosion at organic-aqueous interface in the settlers during pilot plant operation. The settlers were elevated and supported on columns.
4. The mix boxes were equipped with a Davy (now Jacobs Engineering) type double shrouded pump-mix impellers..
5. The large diameter SX piping was in PVC lined FRP, selected on cost basis. The piping suffered damage during transport to site (this was prior to introduction of HDPE to SX plant design).
6. EW used high current density, and the product was subjected to further refining.
7. The plant is still in operation after over 45 years.

ORGANIC SELECTIVITY

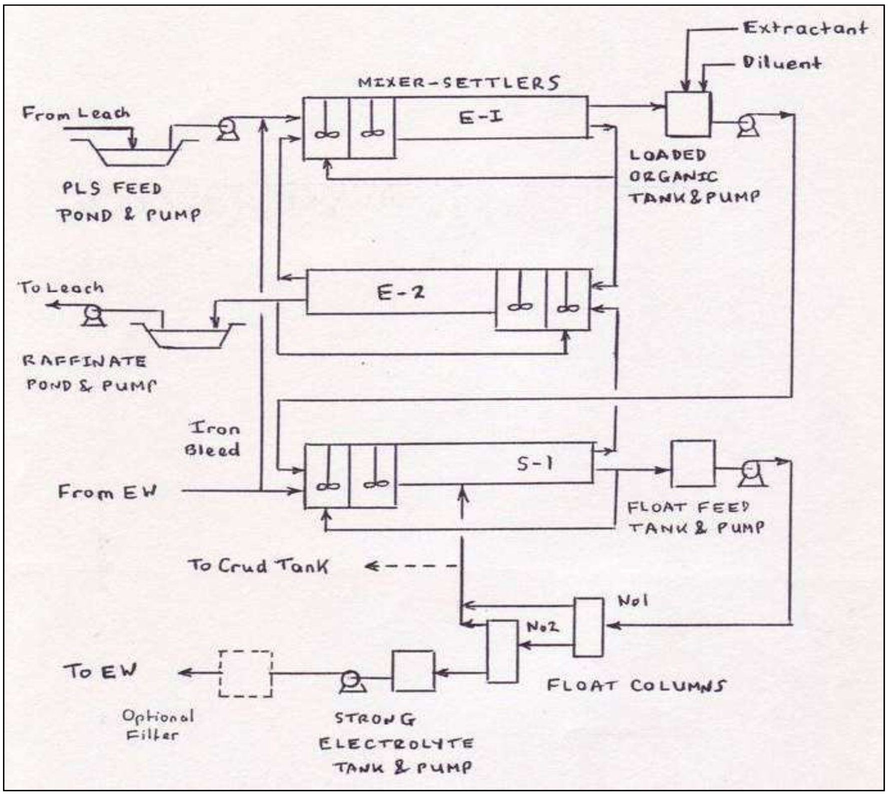
- The only significant element extracted by oxime copper extractants is ferric iron.
- Copper-iron ratio of 500-2500 (under ideal conditions) depending on the particular extractant.
- Actual chemical transfer is affected by the Cu:Fe ratio in the aqueous feed solution.
- There is an additional transfer of both ferrous and ferric by physical entrainment with the organic. This is a particular problem for the loaded organic, as iron reduces current efficiency in EW.
- Other undesirable impurities which can be entrained in loaded organic include chloride, manganese and nitrate.
- Chloride can also be transferred from the leach solution by entrainment to EW which has a very tight specification of 30 ppm Cl maximum.

Notes:

Effect of entrained impurities:

1. If the chloride level in the EW electrolyte exceeds about 30 ppm it tends to attack stainless steel cathode blanks causing difficulty in stripping the copper from the blanks. (However, it should be noted that a low threshold chloride level of about 10 ppm is required as a surface smoothing agent.)
2. If manganese is transferred into the electrolyte circuit it can lead to permanganate formation which can severely degrade the SX organic in the strip circuit. This has happened to a number of operations during commissioning. If manganese is expected to be present, it is advisable to start with a minimum initial buffer of about 0.5 g/L iron and monitor the Eh which should be less than 600 mv, then maintain a ferrous iron/manganese ratio of 8-10/1in the electrolyte when in operation (Ref: Anglo American Chile paper, ALTA 2011).
3. It has been found that a minimum of 1 g/l of total iron is usually necessary to prevent high Eh levels in the electrolyte. At Chuquicamata, Chile, the total iron in electrolyte is 0.4-0.5 g/l to maintain high current efficiencies in the cellhouse. Because of this low level of total iron, a very high solution Eh of 900 mV is generated compared with 400 mV normally. The Eh is reduced by contacting the spent electrolyte with copper scrap in a reduction tower. This reduces the manganese to Mn2+ and renders it benign to the SX organic (Ref: MMS paper, ALTA 2010).
4. Cytec Solvay has introduced ACORGA OR formulations for SX solutions having high ORP (Ref: Cytec paper, ALTA 2011).
5. Nitrate in solution can lead to severe attack on the organic – see next slide.

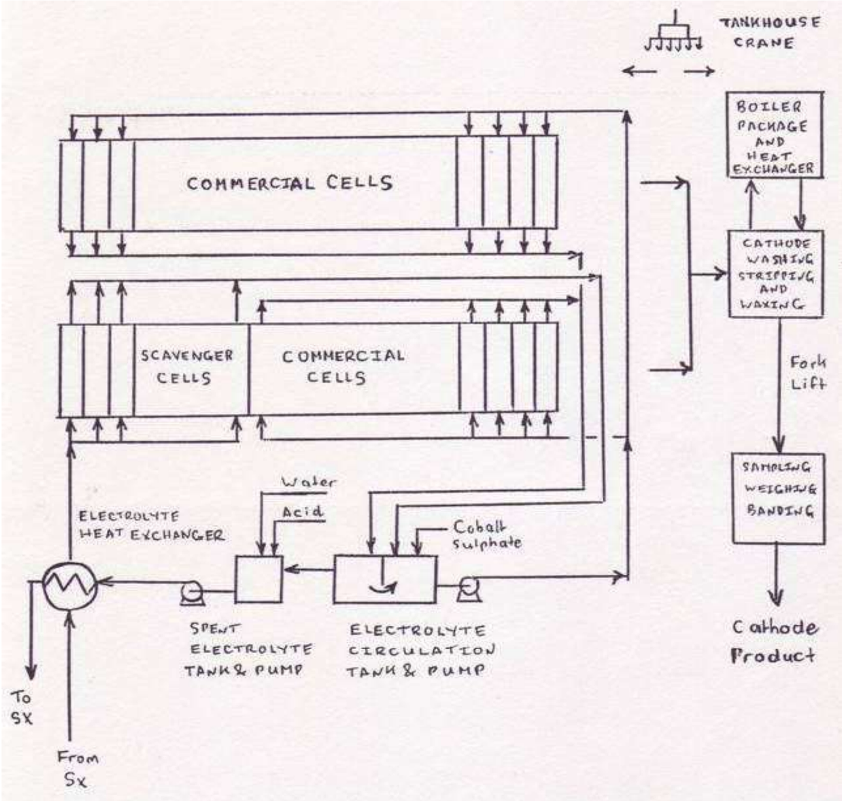
SX FLOWSHEET



Notes:

1. Flowsheet shows a simple single train 2 extraction + 1 strip stage flowsheet typically suitable for relatively low-grade solution from heap or dump leaching.
2. More stages may be added for more concentrated solutions such as from leaching of high-grade ore or concentrates.
3. Two stages of float columns are included as a relatively low cost electrolyte clean-up arrangement. This arrangement would not reduce the organic entrainment to the low level achievable with filters, and would have to be typically backed up by including a sacrificial scavenger circuit in the EW tankhouse. This is just one approach to this duty, and it is recognized that there are a number of alternative arrangements.
4. No organic recovery step is included for the raffinate. Some operations incorporate an organic collection segment into the pond from which organic is retrieved with some kind of skimming device. On occasion, coalescing equipment such as an after-settler or float column is included.
5. Conventional mixer-settlers with two-stage mix-boxes are depicted. It is recognized that alternatives such as reverse flow or VSF type units could be used.
6. Ponds are used for PLS and raffinate surge which is common for heap and dump leach operations. However, it may be appropriate to use surge tanks for more concentrated leach solutions where the flow rate is lower.
7. A small bleed stream is taken from the spent electrolyte returning from EW in order to control the level of iron and/or chloride in the EW circuit. The bleed is added to the first extraction stage to recover the copper content. The acid content flows through to the raffinate and forms part of the acid make-up to leach. If the acid cannot be accommodated in leach (e.g. in some sulphide leaching systems), it may be necessary to treat a raffinate bleed stream with limestone or other acid consumer to neutralize the acid and in some cases precipitate iron. In such cases, it may be necessary to incorporate a copper recovery step to avoid unacceptable copper loss from the bleed steam.

EW FLOWSHEET

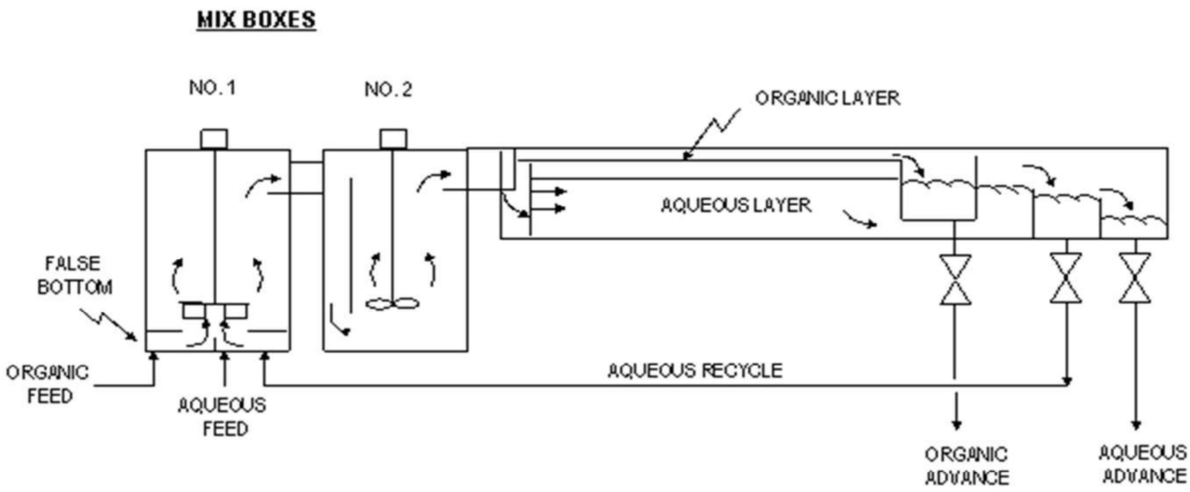


Notes:

1. The flowsheet depicts a simple single aisle EW tankhouse, with a sacrificial scavenger circuit to trap remaining entrained organic. Because of organic collecting on the top of these cells, the use of foam or plastic balls or beads for mist suppression would not be appropriate. Typically these cells could be fitted with some form of covers. If an electrolyte filter is included in the SX section, scavenger cells would not be absolutely necessary, though they could still be included as an added back-up.
2. An electrolyte recirculation tank is included to allow the flow through the cells to be independent of the electrolyte flow rate from/to SX. This tank is typically fitted with a central vertical baffle to allow spent electrolyte to be drawn from the cell discharge solution. Cobalt sulphate make-up is added to the cell feed side of the baffle to maintain a level suitable for minimizing lead input from the anodes. It reduces the affect on anodes of manganese if present and improves anode life. The make-up is required because of the loss of cobalt in the electrolyte bleed to the SX circuit.
3. Some operations include the addition of cathode smoothing agents such as guar.
4. Water and acid make-up are conveniently added to the separate spent electrolyte tank. Water is consumed in the EW reaction and acid and water leave the circuit in the electrolyte bleed. Water make-up should be potable quality with very low chloride content – preferably less than 10 ppm.
5. The electrolyte from/to SX passes through a heat exchanger to keep heat generated in EW in the EW circuit. In some cases, e.g. cold climates, an auxiliary heater may be required. EW operating temperature target range is 40-55oC.
6. The use of stainless steel cathode blanks is assumed, which is the most common present system. Copper starting sheets deposited on permanent stainless steel or titanium blanks were common in the past, and may still be appropriate in some cases – e.g. when the plant is located to an existing supply of starting sheets (further details are provided later in the course).
7. As current densities have increased, the use of smoothing additives has become common, including guar gum, polyacrylamides and modified starches (polysaccharides), such as the oligosaccharide product DXG-F7 which is widely used particularly in Chile.

CONVENTIONAL MIXER-SETTLER (CONT.)

SIDE VIEW



Notes:

1. Organic and aqueous phases are contacted in mix boxes typically equipped with slow speed, large diameter, low shear pump-mixer type agitators which provide inter-stage pumping as well as mixing. Pump-mixers commonly have variable speed drives, and are designed to minimize fine droplet formation and air entrainment which hinder coalescence in the settlers and lead to entrainment losses. Auxiliary mix boxes and agitators are commonly used (as above) for large plants to avoid mixing inefficiencies which can occur with large mix boxes, and to achieve a lower profile.
2. In the adjoining settler, the phases coalesce and separate by gravity, and are removed via separate weir boxes. The overall solution level is generally set by a fixed organic weir, while the thickness of the top organic layer is set by an adjustable aqueous weir or by an adjustable sleeve on the discharge pipe in the aqueous weir box.
3. The mix boxes can be operated either with the organic or the aqueous as the continuous phase. Organic continuous is commonly used for the final extraction and first stripping stages, with aqueous being used in other stages. However, other conditions can be adopted as appropriate. Where appropriate, one of the phases is recycled from the settler to achieve an internal mix box O/A ratio favourable for achieving and maintaining the desired phase continuity – ie a slight excess of the designated continuous phase.
4. Mix box retention time varies with the properties of the organic and aqueous solutions. For copper circuits, it is typically around 2 minutes total for each stage.
5. Mix boxes can be cylindrical or “square” and fitted with various baffle designs to reduce air entrainment and minimize short circuiting.
6. Settlers are generally rectangular (though circular settlers have been used).
7. Devices such as flow distributors, picket fences and various coalescence aids are installed in the settler to improve performance.
8. Phase separation rates in the settlers are relatively slow, and the specific flow is typically 3-6 m3/h (of combined aqueous and organic) per m2 of settler area, with the low end of the range used for low solution temperature and/or for high concentration organic phase.
9. Materials used include FRP, stainless steels, and concrete with various stainless, FRP or HDPE. Linings.
10. Covers are generally fitted for outdoor units to minimize organic evaporative losses, keep out dust, and minimize heat loss. Indoor units sometimes have open tops.

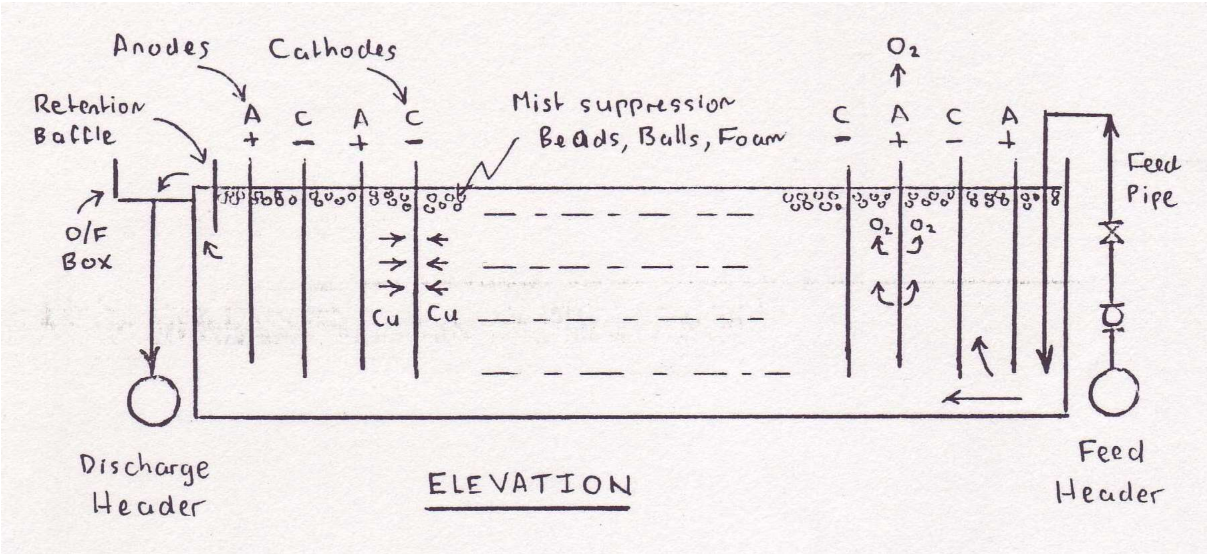
REVERSE FLOW SX PLANT

(Ref: Piedras Verdes Operation, Mexico, Bateman [Now SGS])

Notes:

Reference: “Bateman Settler Commissioning”, M.F. Vance's, Bateman SX, ALTA Copper 2007.

EW CELLS



Notes:

1. Electrolyte feed is typically introduced via a manifold pipe located at the bottom of the cell and passing along the length of the cell on both sides, especially for long cells. Short cells may be fitted with a simple feed at one end.
2. Anode materials: generally rolled lead based alloys including elements such as calcium, tin and strontium (lead-calcium-tin is the most common)
3. There is a recent trend towards coated titanium anodes.
4. Cathodes are generally 316 stainless steel blanks with 2B finish. Copper starting sheets are still occasionally used. Titanium blanks can be used if it proves difficult to keep the chloride in electrolyte below 30 ppm – e.g. when a chloride leaching system is used. There has been a trend towards lean duplex stainless steel which facilitates automated cathode stripping, and higher current densities,
5. Anodes and cathode plates are typically sized for product cathodes measuring 1 m wide x 1-1.3 m deep.
6. The number of anodes and cathodes is a balance between capex and opex. Typical number of cathodes has been 30-66 – divisible by 3 to allow live pulling of one third of the cathodes. Live pulling of a greater proportion may overly increase the current density on the remainder, with risk of adversely affecting quality.
7. There is a recent trend towards “jumbo” cells with typically 84 cathodes of which half is pulled.
8. Typical current density range is 230-420 A/m^2. The high end of the range yields lower capex, but the spent electrolyte copper content needs to be higher to maintain high current efficiency.
9. The cathode cycle time between pulls is typically 5-8 days.
10. Operating current efficiency is typically 87-95%.
11. Cathode weight is 50-90 kg depending on harvesting cycle time, current density and cathode dimensions.
12. Cells are typically polymer concrete construction. Plasticised PVC lined concrete was commonly used in the past. Also FRP cells and other plastic linings have been used for small plants.

PARTIALLY OPEN SIDED EW TANKHOUSE
TENKE FUNGURUMI, DRC

(Ref: TFM paper, ALTA 2013)

Notes:

1. Example of partially open sided EW arrangement for a warm climate.

2001 FIRE AT OLYMPIC DAM

(Ref: IPDS presentation, ALTA 2005)

Notes:

1. The fire started in the copper SX tank farm area and spread to other facilities.
2. The cause was not conclusively determined. However, the most probable cause was deemed to be the ignition of crud inside the loaded organic pipe by a static electrical spark, subsequently igniting the inner wall of the HDPE pipe, eventually breaching the pipe wall.
3. Although the fire did not reach the mixer-settlers, the entire plant was out of commission for an extended time period with significant production loss.

References:

- South Australian Metropolitan Fire Services website.
- South Australian Metropolitan Fire Services Investigation, B. Walker.

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SX-EW SHORT COURSE

EXAMPLE SX-EW PLANT DESIGN

1. PLANT DESIGN CRITERIA

1.1 GENERAL

a) PRODUCTION

PLANT CAPACITY t/a CATHODE	13,500	

b) OPERATING SCHEDULE

	h/d	24
	d/y	365
OVERALL UTILISATION/AVAILABILITY	%	95

1.2 ASSOCIATED PLANT (EXCLUDED)

ORE TYPE		OXIDISED COPPER
LEACH SYSTEM		HEAPS
COPPER GRADE	%	1
NOMINAL CRUSH SIZE	mm	25

1.3 SOLVENT EXTRACTION

a) EXTRACTION SECTION

FEED SOLUTION		
- FLOWRATE	m^3/h	500
- COPPER	g/L	3.5
- TOTAL IRON	g/L	5.0
- FERRIC IRON	g/L	1.0
- pH		2.0
- CHLORIDE (MAXIMUM)	mg/L	75
SOLIDS (MAXIMUM)	mg/L	20
COPPER RECOVERY	%	93
TEMPERATURE - DESIGN	°C	20
- MAXIMUM	°C	30
RAFFINATE COPPER	g/L	0.245
RAFFINATE FLOWRATE (EXCL. IRON BLEED)	m^3/h	500
NO. OF STAGES	2	