
Hydromet
101 Basics


Sx Leach
Water Dogs

Safety: Consequence Thinking

Definition: Consequence thinking is taking the time to think through a task, identifying and controlling all energy sources, including behaviors so that injury to myself or others will not occur.

- Consequence thinking is the standard for what we do. Doing a task the way it's been done for the past 20 years is not acceptable, if there is uncontrollable energy in the task.
- For an injury to occur, three things must be present: Energy, exposure, and an event/trigger.
- Removing any one of the components and the injury will not occur.

PPE for the leach Dumps

LOTOTO:

Always follow your site's Hazardous Energy Control Program(LOTOTO)
Be aware that energy sources come in many different forms and include Mechanical, Pneumatic, Hydraulic, Chemical, Atmospheric, Electrical, Thermal, Kinetic, Gravitational, Ionizing Radiation and/ or residual or stored energy.

Fit for Duty:

To be fit for duty, Employees Must show up on time and must be mentally, physically and emotionally prepared to perform their work duties in full compliance with site expectations.

Communication

- Federal Communications Commission (FCC) regulations require all transmissions be in English and that radios be used for "business only" communications.
- Abuse of radios through inappropriate comments, intentional interference personal chitchat, or any other non-business related communication will not be tolerated and will lead to discipline up to and including discharge from FMI. Contractor personnel may be placed on the Freeport McMoRan No Trespass List for non-compliance with this policy.

HDPE Pipe Handling Procedures

Due to the High Energy Incidents that have occurred in the past, an FMI steering team, a collaboration of subject matter experts, was established to develop Safe HDPE Pipe Handling Guidelines & Permit.

This guideline applies to all Freeport-McMoRan employees and contractors who handle High Density Polyethylene (HDPE) pipe, including deliveries of new pipe of any length.

FREEPORT-MCMORAN

HDPE Pipe Handling Policy

Health and Safety FCX-HS12 | Release Date 1/18/2019

POTENTIAL FATAL RISKS

Uncontrolled Release of Energy
Lifting Operations
Vehicle Impact on Person

CRITICAL CONTROLS

- Segregation, Guards, Barriers & Barricades
- Tensioned Lines Management
- HDPE Management
- Energy Isolation
- Mechanical Integrity of Lifting Equipment
- Lifting Execution
- Vehicle Preoperational Inspection
- Positive Communication System
- Fundamentally Stable Parking

TECHNICAL SUPPLEMENTS

HDPE Pipe Pulling Force Reference
HDPE Pipe Handling Permit
Push/Pull/Positioning Illustrations
Rigging Approval
HDPE Pipe Handling Engineering Review
Receiving/Loading/Unloading Checklist
HDPE Pipe Shipping Requirements
Approved Rigging Assemblies

TRAINING REQUIREMENTS

All employees and contractors handling HDPE pipe must be trained in this policy and required skills
HDPE Pipe Handling (Initial and Refresher)
HYD_FCX2027C & HYD_FCX2024C)
HDPE Pipe Fusing (HYD_MTI1002C)
HDPE Skills training/assessments
HDPE Datalogging (HYD_MTI1003C)
Technical Rigging (RIG_FCX1001C)
Remedial Training as necessary

POLICY

OVERVIEW

Permit is required for handling all pipe 2in. (5cm) in diameter or larger and longer than 50ft. (15.24m).
All deliveries require a receiving/loading/ unloading checklist.
SOPs will be developed for activities around HDPE receiving, offloading, storage, pulling and installation, and coiled pipe.
Reference documents use is mandatory.
Engineering reviews and MOC may be required for new installations or major changes.

ACTIONS TO STAY SAFE

Conduct pre-job safety reviews.
Always complete all required permits and checklists.
Verify that equipment in use has adequate lifting/pulling capacity.
Task train employees for all equipment in use with HDPE.
Follow all SOPs when working with HDPE.
All personnel must remain 50ft. (15.24m) or more away from pipe being moved or handled, or utilize substantial barriers.
Personnel directly involved with handling activities and within 50ft. (15.24m) of HDPE must ensure pipe is controlled and blocked as necessary.
Eliminate interaction with traffic or utilize appropriate blocking during pulls.
Consider increased stored energy when bending pipe and install barriers as needed.

RECEIVING, OFFLOADING AND STORAGE

Complete load receiving/loading/unloading checklist.
Receiving personnel will coordinate with operations on all HDPE deliveries.
Establish 50ft. (15.24m) safe zone fully around truck being unloaded.
Safe zones must be demarcated.
Truck drivers will stay with Safety Watch(es) when unloading HDPE.
FCX vehicles moving pipe will have engineered controls to secure pipe.
Barriers/blocking will be utilized when unstrapping pipe.
Without engineering controls:
Store pipe 10in. (.25m) in diameter or larger no more than two pipes high.
Store pipe less than 10in. (.25m) in diameter no higher than 2ft. (.61m).

PULLING OR MOVING LENGTHS OF PIPE

Complete permit before moving/pulling pipe.
Reference the approved rigging assemblies.
Never use a sling as a choker on 12in. (.3 m) or larger pipe without variance.
Never cut, slot, or shape the pipe for anchorage points.
Use escorts equipped with blue lights, spotters and blockers when pulling or moving pipe when there is a potential for interaction with traffic.
Rigging used for pulling must be identified and cannot be used for lifting.

Environmental

Procedures and Policies

- Follow all procedures
- Report all spills to your supervisor immediately
- Know your department`s Discharge Plan

Metallurgical

- Stockpile Leaching requires the excavation of the ore then transported to a leaching pad.
- In Leaching operations there are typically 2 versions of stockpile leaching – Crushed and Run of Mine (ROM) Ore.
- Crushed ore is high grade ore that is crushed to a desired particle size distribution prior to leaching.
- ROM ore is low grade ore that is not economical to crush and is simply placed on a pad for leaching.

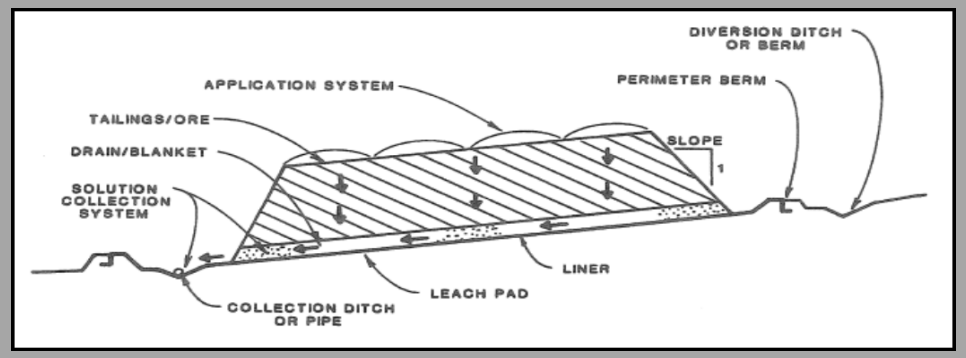
Crushed

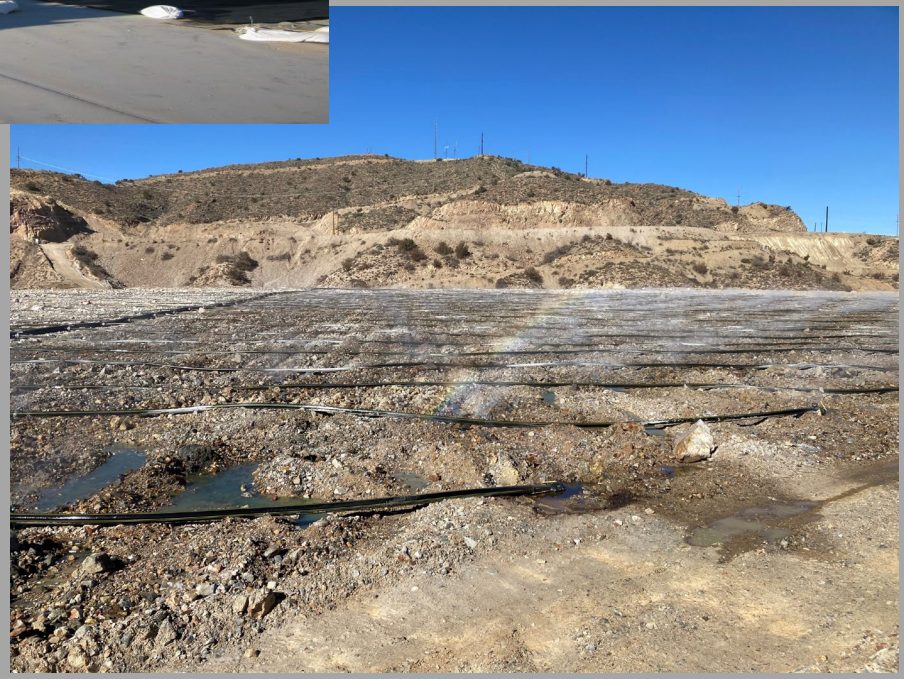
Run of Mine (ROM)

Metallurgical

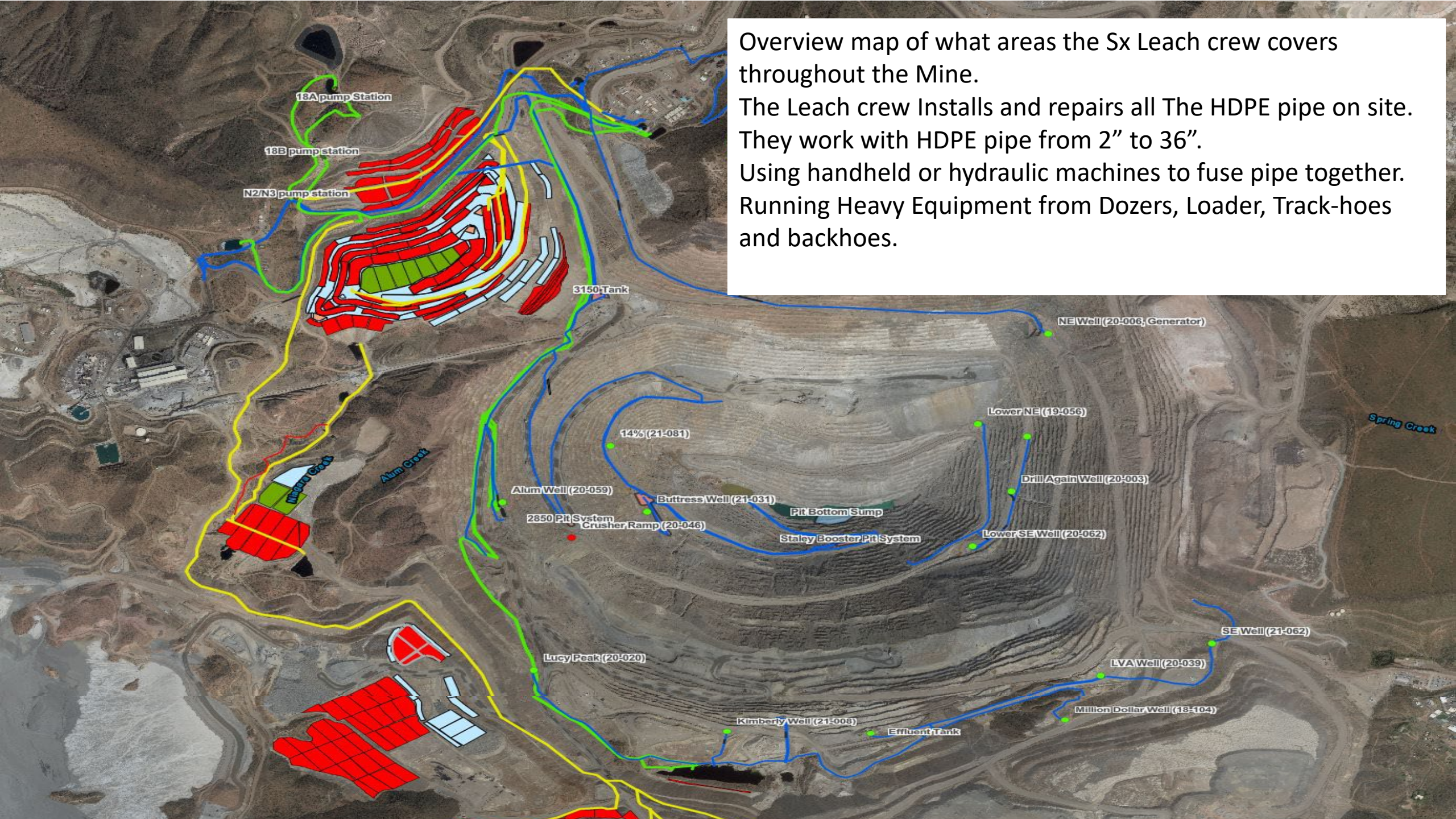
Leach Pad Construction Liner and Collection System Design

- The goal of the liner is to prevent PLS from entering the soil below the pad. Some ROM stockpiles do not have a liner underneath.
- The collection system is designed to expedite and contain PLS exiting the stockpile.
- A pad without a collection system may experience phreatic head (or internal ponding) which will cause pad instability (blowout).



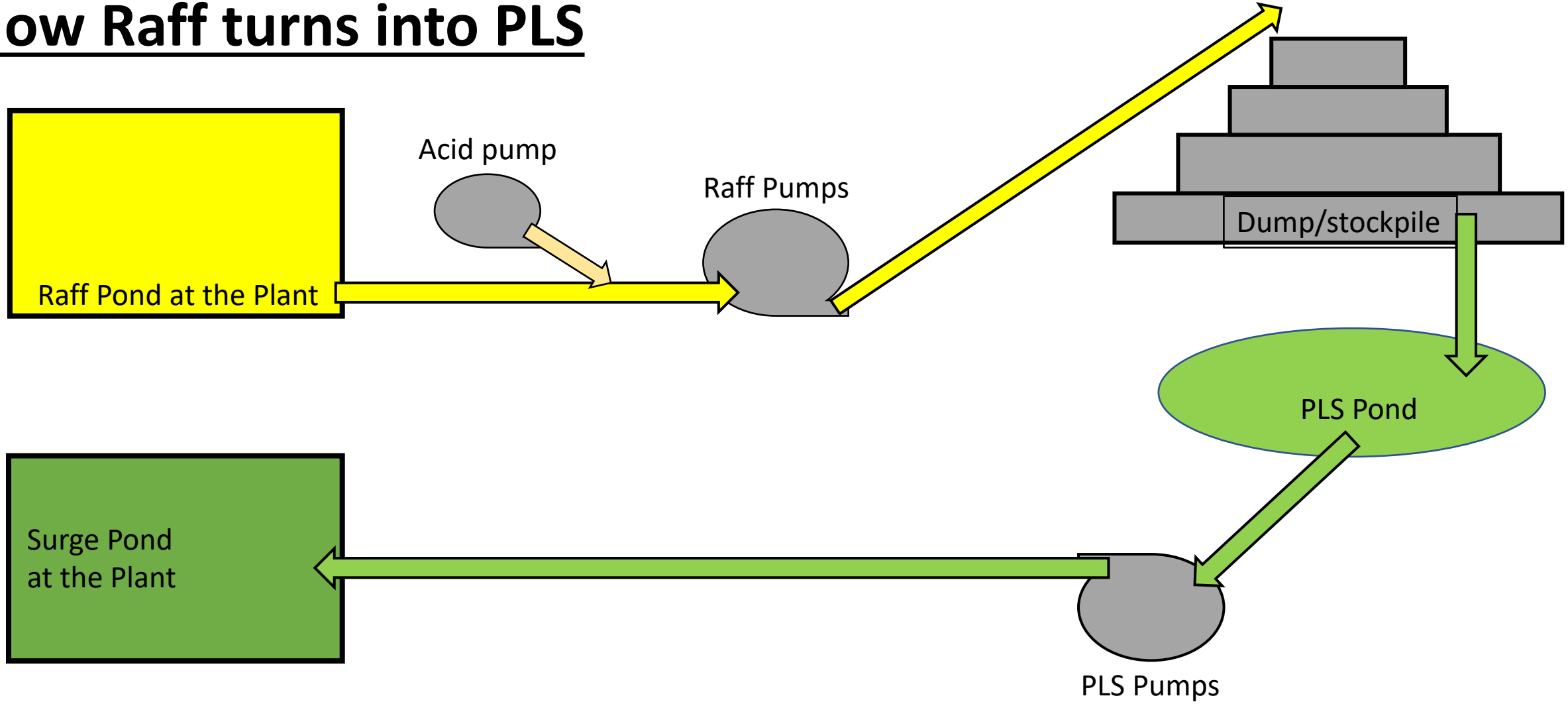


- The leaching of stockpiles is dependent upon the delivery of raffinate to the ore.
- Leaching systems are typically unsaturated.
  - Although saturated conditions may exist in certain areas (Ponding).
  - Saturated conditions occur due to **high clay** or **fines content**, **segregation**, **compaction** or **poor ripping.**



Overview map of what areas the Sx Leach crew covers throughout the Mine.
The Leach crew Installs and repairs all The HDPE pipe on site.
They work with HDPE pipe from 2” to 36”.
Using handheld or hydraulic machines to fuse pipe together.
Running Heavy Equipment from Dozers, Loader, Track-hoes and backhoes.

How Raff turns into PLS



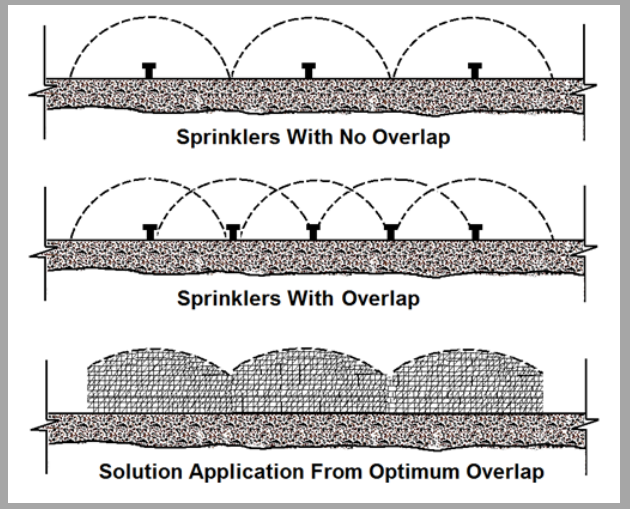
Irrigation Equipment

Leaching Solution Delivery Methods. Four solution spreading devices in use today. Each solution spreading system is different and Made of either PVC or HDPE.

Rotating Impact Sprinklers, Wobblers and D-Ring sprayers. Require pressurized lines to operate. The amount of pressure required can vary from 20 to 25psi.

- Put in configuration to maximize solution spread.
- Line spacing for optimum effectiveness.

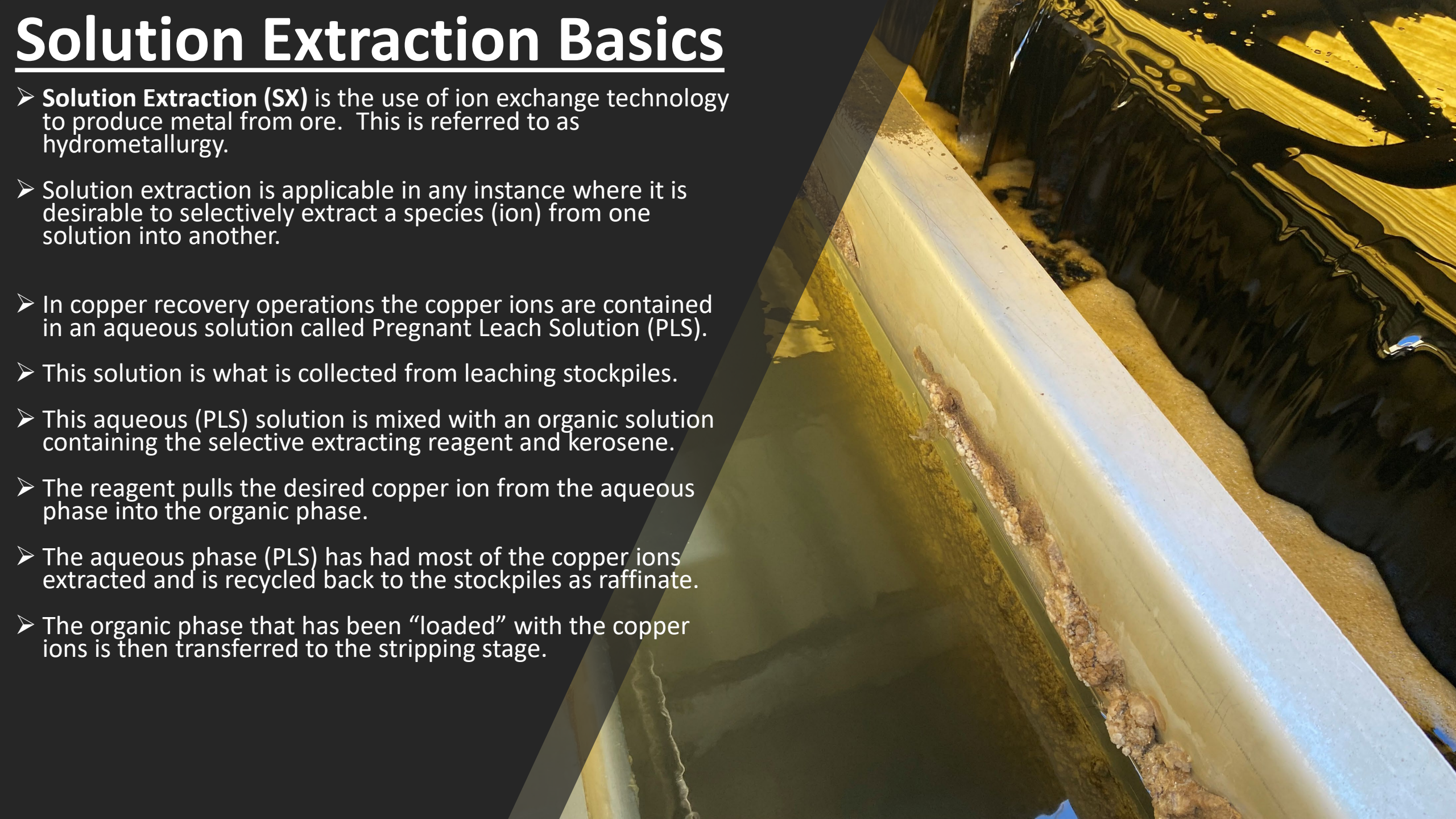
Drip Lines are a method with small emitters.

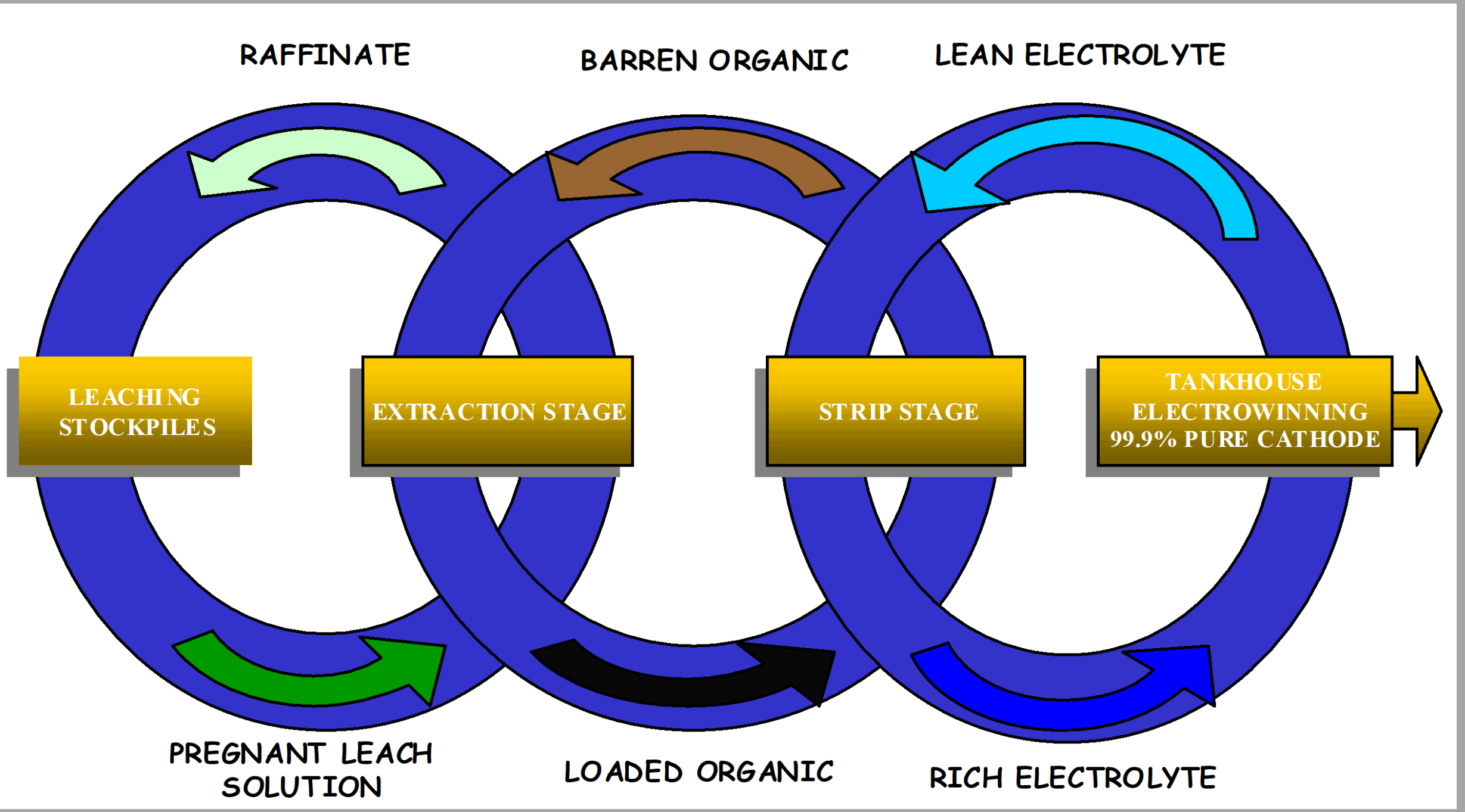


SX-EW

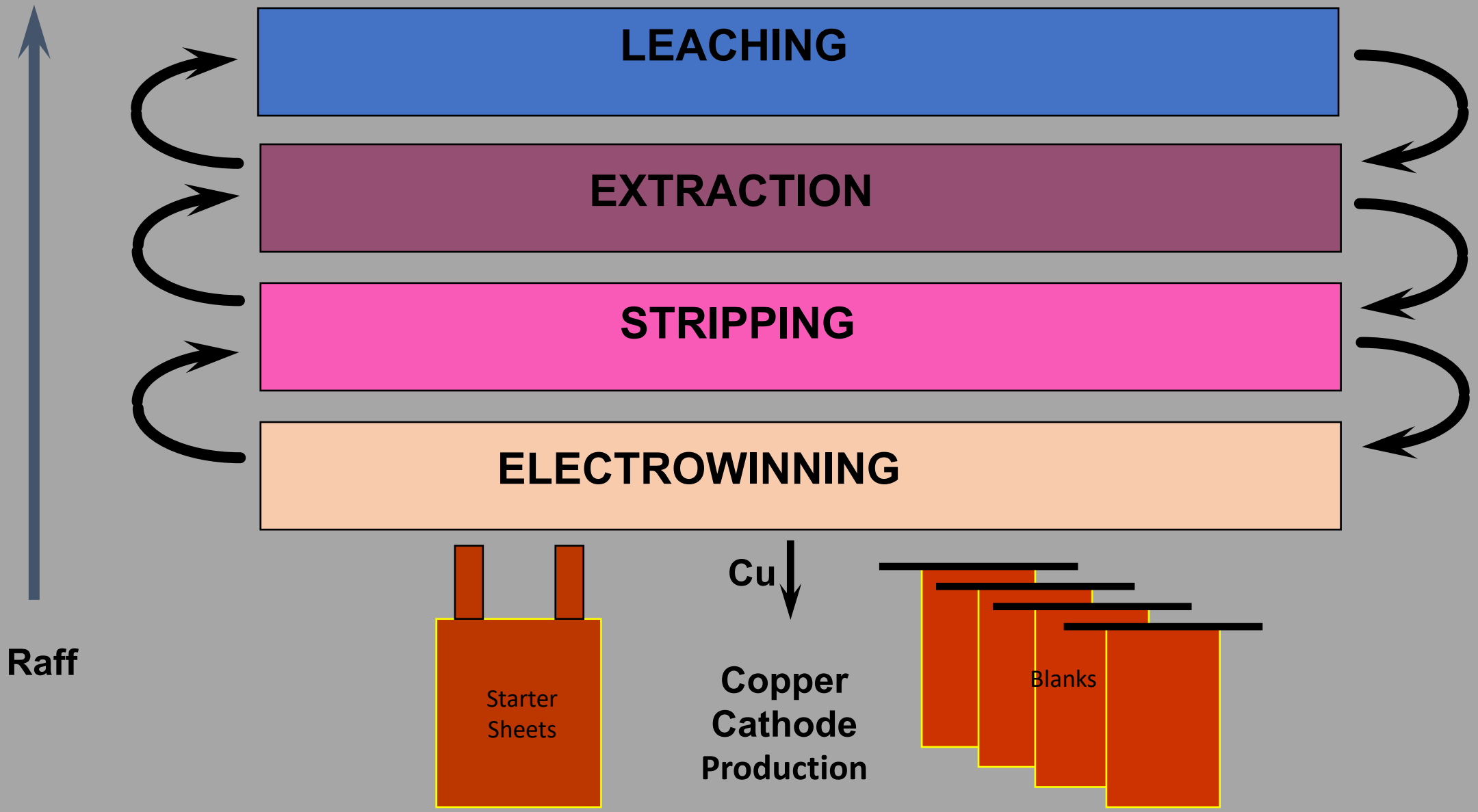
Solution Extraction Basics

- **Solution Extraction (SX)** is the use of ion exchange technology to produce metal from ore. This is referred to as hydrometallurgy.
- Solution extraction is applicable in any instance where it is desirable to selectively extract a species (ion) from one solution into another.
- In copper recovery operations the copper ions are contained in an aqueous solution called Pregnant Leach Solution (PLS).
- This solution is what is collected from leaching stockpiles.
- This aqueous (PLS) solution is mixed with an organic solution containing the selective extracting reagent and kerosene.
- The reagent pulls the desired copper ion from the aqueous phase into the organic phase.
- The aqueous phase (PLS) has had most of the copper ions extracted and is recycled back to the stockpiles as raffinate.
- The organic phase that has been “loaded” with the copper ions is then transferred to the stripping stage.



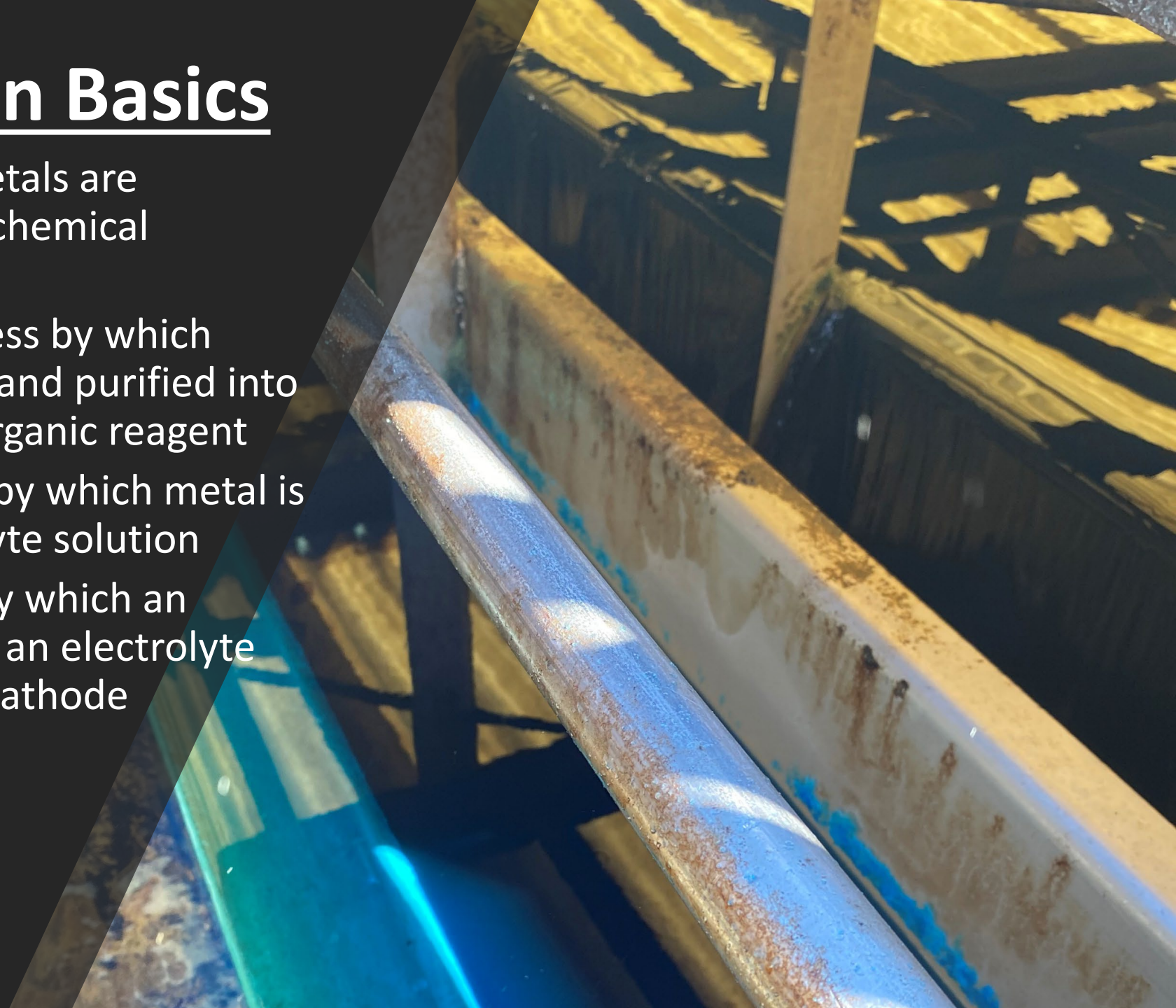

RAFFINATE
BARREN ORGANIC
LEAN ELECTROLYTE
LEACHING STOCKPILES
EXTRACTION STAGE
STRIP STAGE
TANKHOUSE ELECTROWINNING 99.9% PURE CATHODE
PREGNANT LEACH SOLUTION
LOADED ORGANIC
RICH ELECTROLYTE

LEACHING / SX /EW



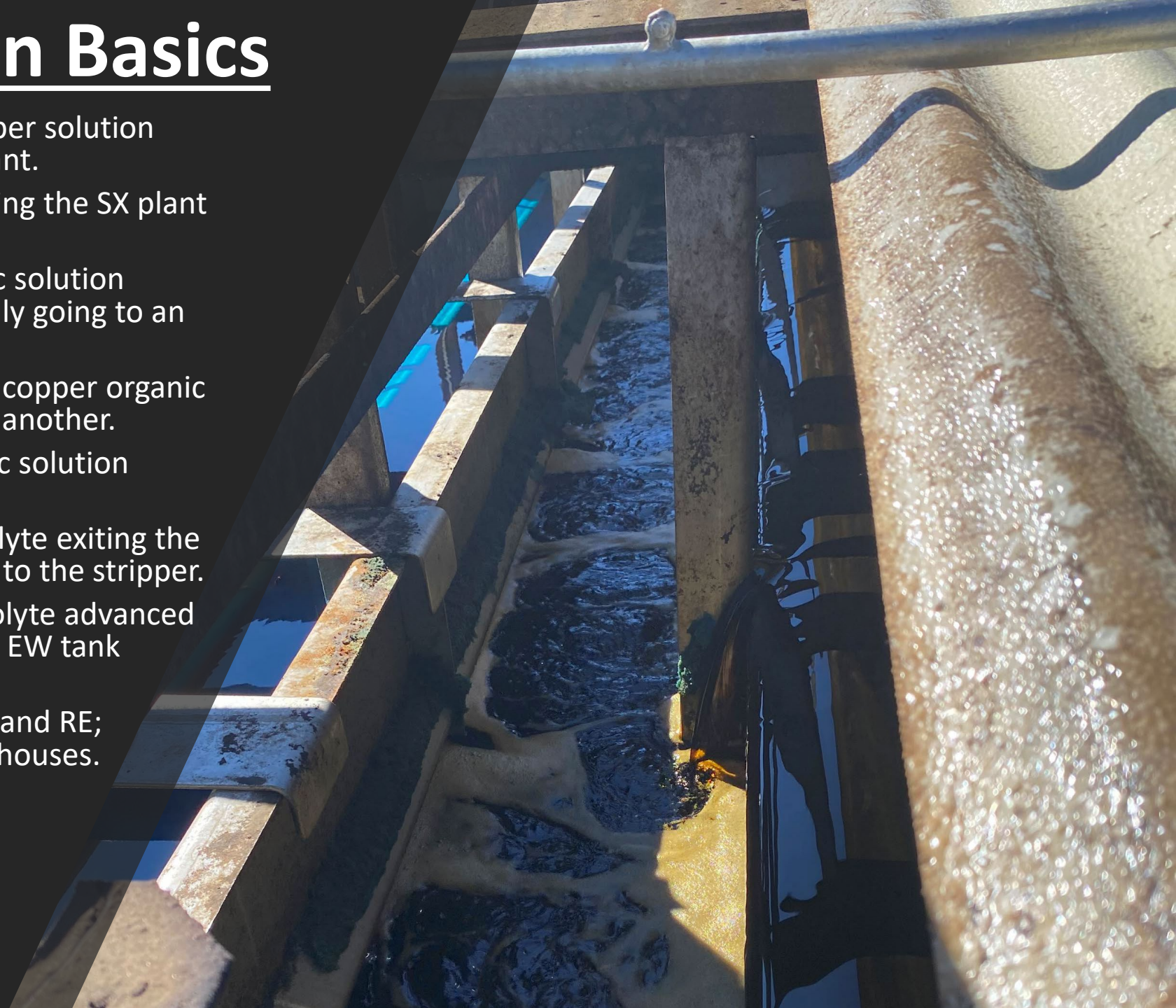
Solution Extraction Basics

- **Leaching:** process by which metals are removed from ore via various chemical reactions
- **Solution Extraction (SX):** process by which leach solution is concentrated and purified into an electrolyte via a selective organic reagent
- **Electrowinning (EW):** process by which metal is electroplated from an electrolyte solution
- **Electrorefining (ER):** process by which an impure anode is dissolved into an electrolyte and electroplated into a pure cathode



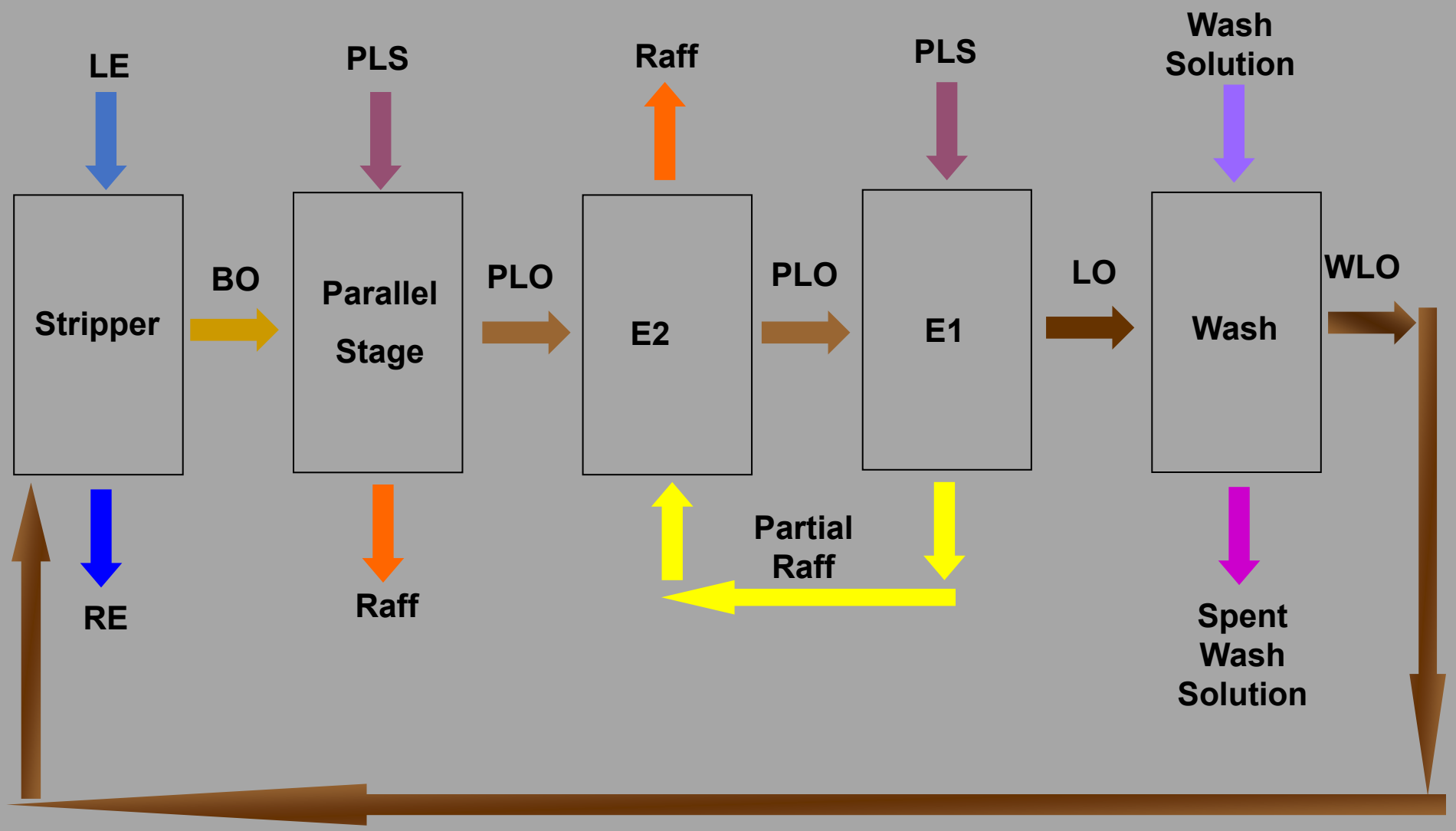
Solution Extraction Basics

- **Pregnant Leach Solution (PLS):** high copper solution coming from the leach pads to the SX plant.
- **Raffinate (raff):** low copper solution exiting the SX plant going to the leach pads.
- **Barren Organic (BO):** low copper organic solution advanced from the stripper and eventually going to an extractor.
- **Partially Loaded Organic (PLO):** medium copper organic solution advanced from one extractor to another.
- **Loaded Organic (LO):** high copper organic solution advanced from an extractor to a stripper.
- **Lean Electrolyte (LE):** low copper electrolyte exiting the EW tank house and eventually advanced to the stripper.
- **Rich Electrolyte (RE):** high copper electrolyte advanced from the stripper eventually going to the EW tank house.
- **Commercial Electrolyte (CE):** a mix of LE and RE; creates the commercial feed to the tank houses.



Basic SX Flow Diagram

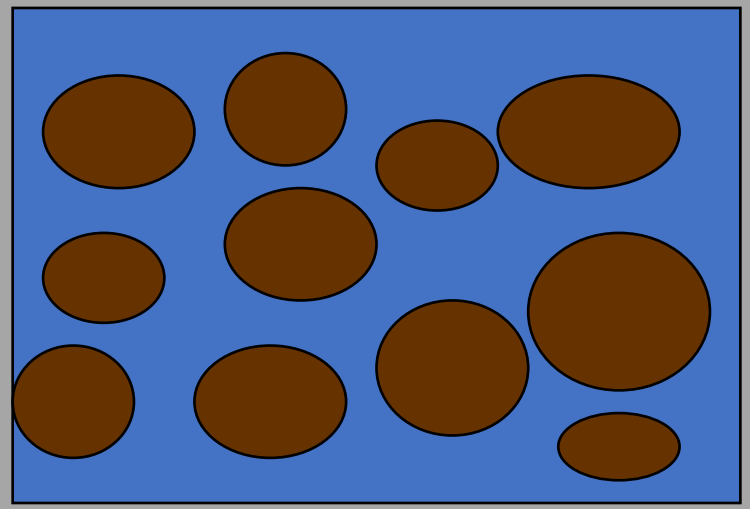
Many different configurations are in use, those with and without wash stages, with and without parallel stages, some have separators to remove aqueous and solids from the loaded organic , etc.



Solution Extraction Basics

Aqueous Continuous

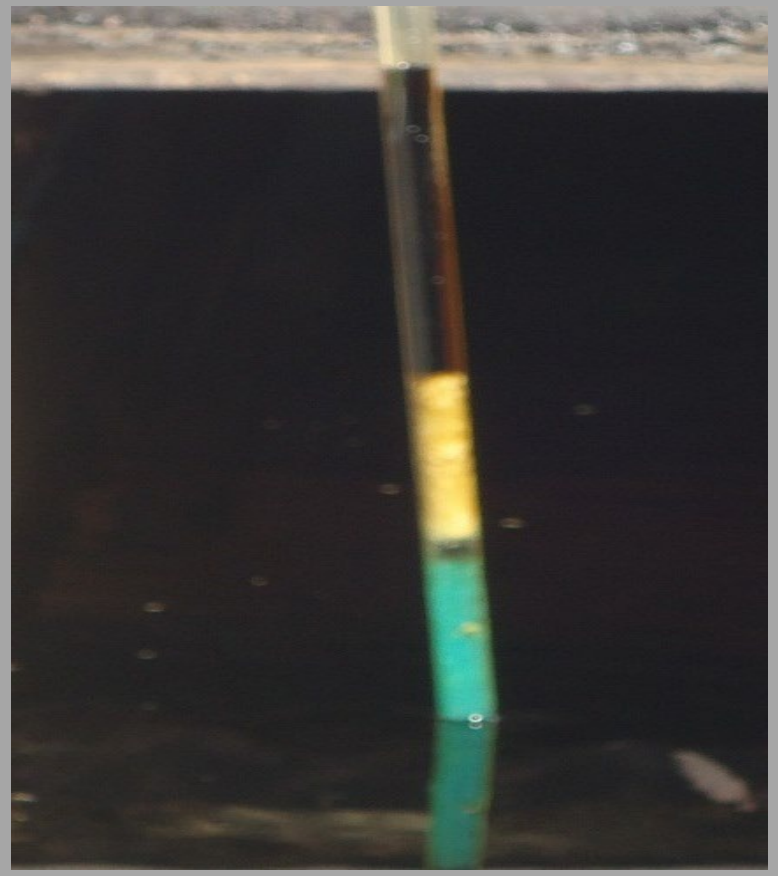
- Droplets of organic in an aqueous matrix.
- Conductive.
- Normally immune to both destabilization of continuity and fluctuation in dispersion band.
- Usually reduces A in O entrainment and so is operated in E1 or W1.
- May entrain air from the surface of the mixer and thus does not pack crud well.
- Surfactants can flip phase from organic to aqueous.
- Generally stable at mixer O/A's of less than 1.

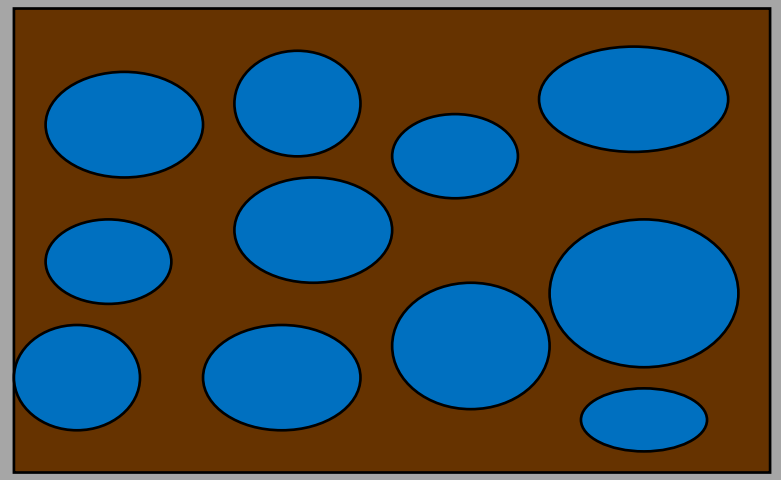


Solution Extraction Basics

Organic Continuous

- Droplets of aqueous in an organic matrix.
- Non-conductive.
- May be destabilized by solids so that the phase continuity will seemingly spontaneously flip to aqueous continuous.
- Dispersion band may vary greatly as a function of solids present; the more solids, the faster the phase disengagement.
- Usually reduces O in A entrainment and therefore is the preferred continuity for E2, PS (Parallel Stage) and S1 which have an aqueous exit stream.
- Packs crud well.
- Generally stable at mixer O/A's greater than 1.

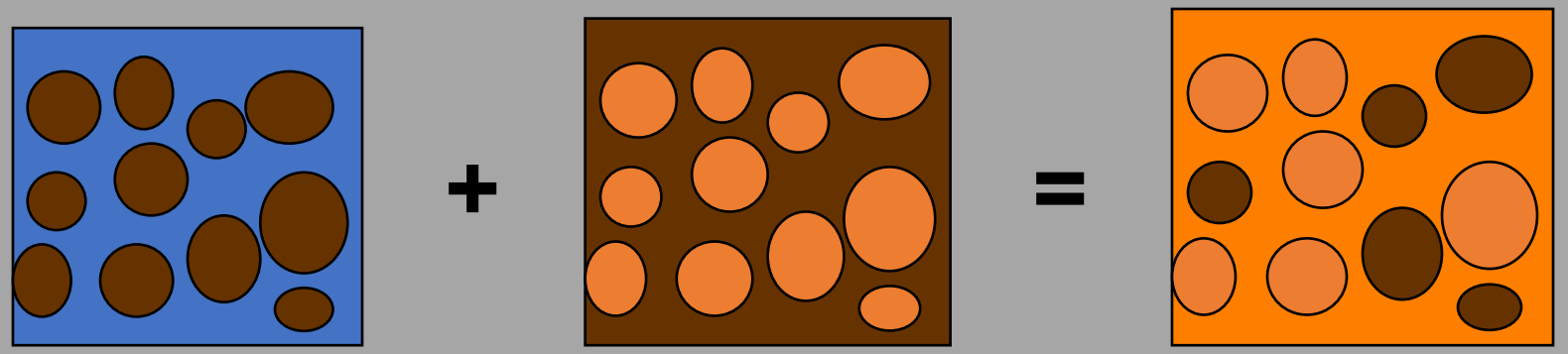




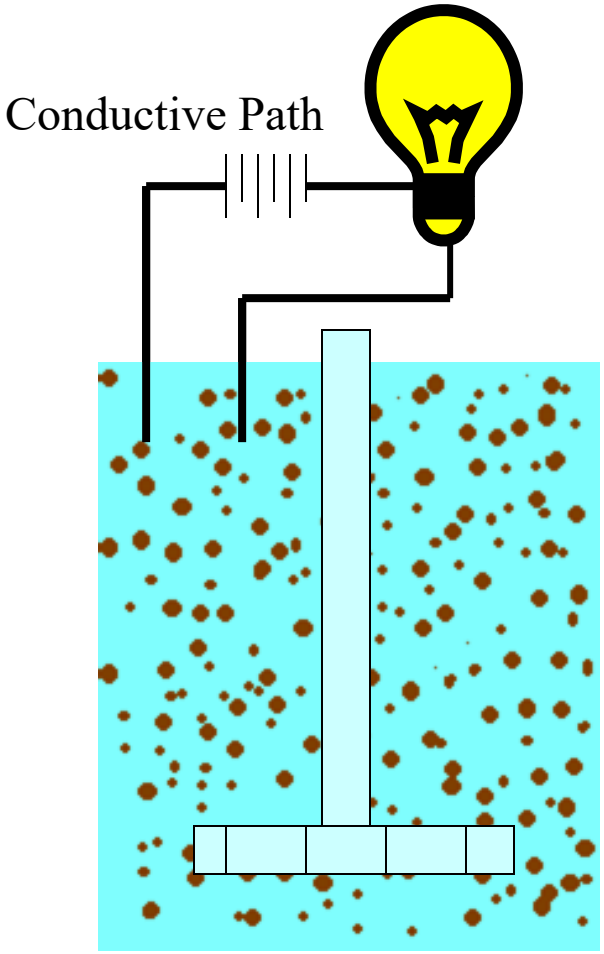
Solution Extraction Basics

Dual or Mix Phasing

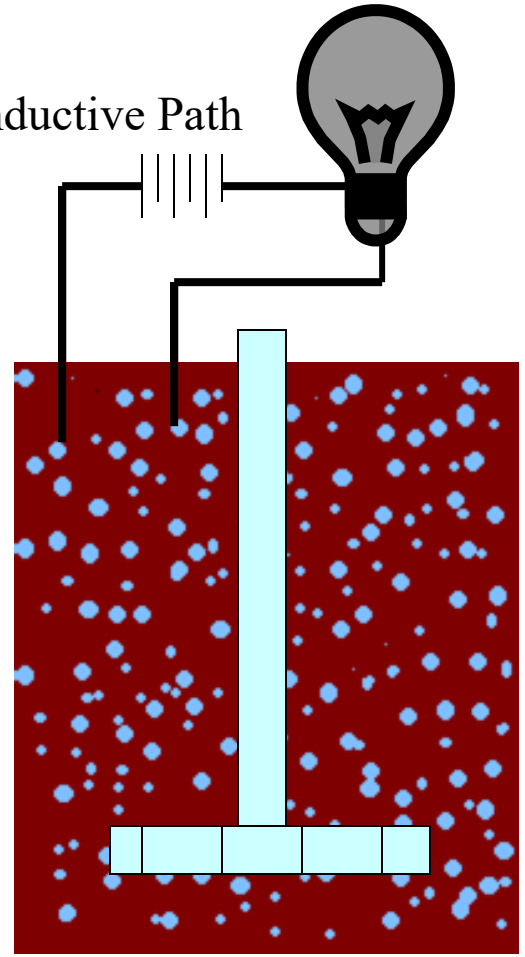
- Where both aqueous continuous and organic continuous phases exist simultaneously.
- Gives the mix box a “grainy” appearance.
- Causes more entrainment to occur.
- Due to phase instability, This can be controlled by changing your O/A ratio.



Mixing Continuities



Aqueous Continuous



Organic Continuous

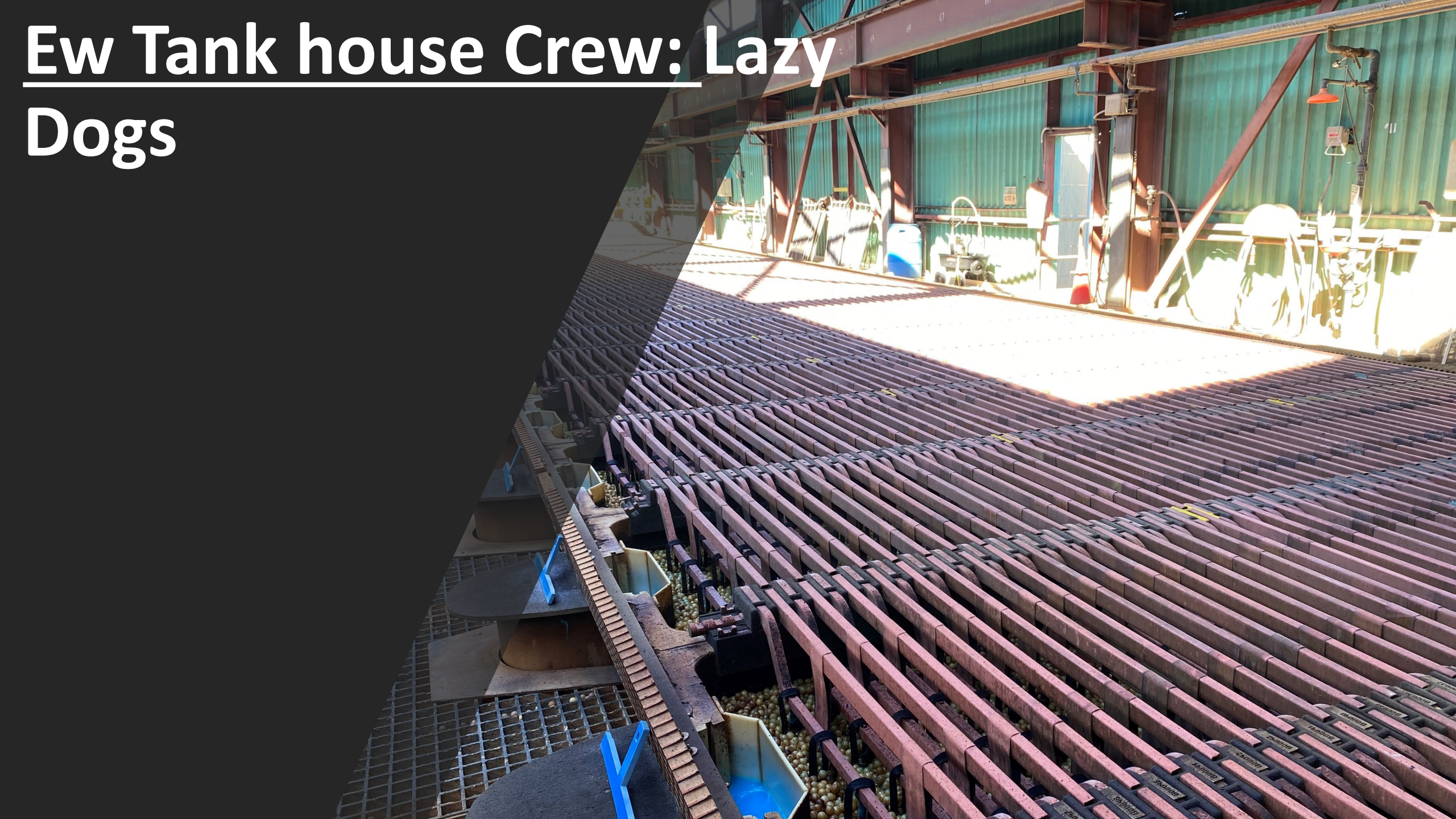
Solution Extraction Basics

- **Electrolyte Filters:** filters designed to remove solids and organic from RE before entering the tank house
- **Mist Suppressant:** chemical added to electrolyte to decrease the surface tension thereby reducing the amount of electrolyte on oxygen bubbles
  - Licorice
- **Smoothing Agent:** chemical added to the electrolyte to slow cathode growth to produce a smoother, denser deposit
  - Guar and starch for example as smoothing agents
- **Cobalt:** If needed is added to the electrolyte to control the corrosion of the lead anodes. Helps increase the size of the lead flakes so that if spalls off in bigger sections to reduce inclusions in the cathode.

ACID USAGE IN SX

- Acid concentration of lean electrolyte must be maintained.
- Too high of a concentration is a waste of resources & can cause pitting of stainless-steel blanks and loop deterioration.
- Sulfuric acid is the source of the hydrogen ion in the copper\hydrogen ion exchange.
- Additional sulfuric acid is needed to aid the stripping process

Ew Tank house Crew: Lazy Dogs



Electrowinning (EW)

- Electrowinning is the final step of the hydrometallurgical process used for producing copper cathodes.
- It is important to understand the two types of electro-chemical cells.

Galvanic cells are ones in which a spontaneous reaction is used to generate a flow of current or electrons. These cells turn chemical energy into electrical energy.

- Examples are dry cells such as flashlight batteries, and automotive style lead storage batteries.

Electrolytic cells are ones in which normally *non-spontaneous* chemical reactions are forced to occur by applying electrical energy from some outside source, such as an alternating current (AC) to direct current (DC) rectifier.

- In these cells, electrical energy is used to cause a desired electro-chemical reaction to occur.
- Examples are the charging of a “dead” battery, or the oxidation of water into hydrogen and oxygen gas.
- An electrowinning tank house uses electrolytic cells to produce copper cathodes.

Electrolyte Circuit

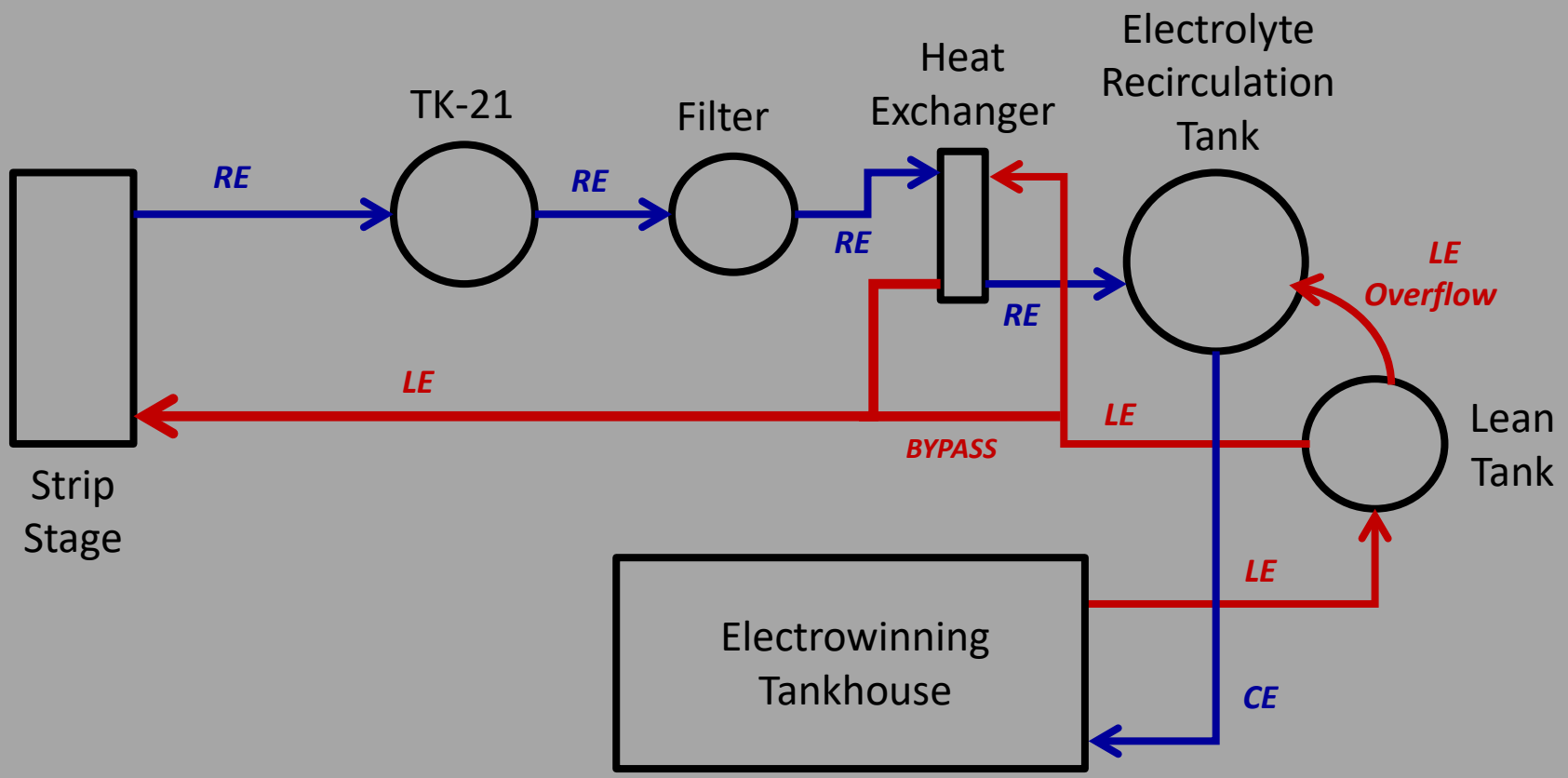
- The rich electrolyte flows from the strip stages to a tank or storage reservoir in the tank farm, then it is filtered, preheated and pumped to the tank house.
- The commercial electrolyte is pumped to the tank house where it circulates through cells.
- The lean electrolyte exiting the tank house flows to a “recirculation tank”.
- This tank may be a separate tank; or an inner tank, or a partitioned off portion of the recirculation tank.
- Regardless of the configuration, the majority of the lean electrolyte overflows into the recirculation tank.
- Some of the lean electrolyte is pumped through the heat exchangers back to the mix box of the strip stages or directly back to a tank at the Sx plant.

• Electrolytes – Relationship

We now have three distinct types of electrolyte:

- **Rich Electrolyte (RE)** from the strip stages.
  - High in copper content, low in acid content.
- **Lean Electrolyte (LE)** from the electrowinning tank house.
  - Low in copper content, high in acid content.
- **Commercial Electrolyte (CE),** mixture of RE and LE.
  - Copper and acid content between the values of the RE and LE.

Typical Electrolyte Circuit



Entrainment

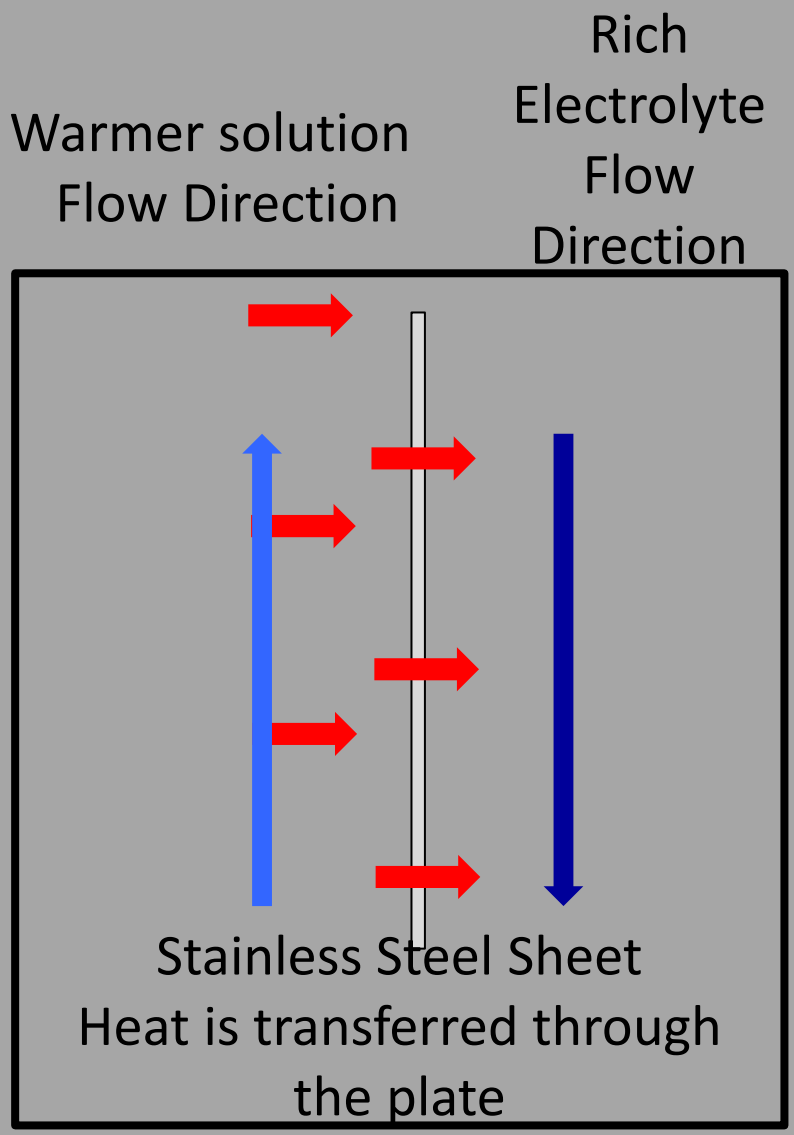
- The electrolyte from the strip stages of the SX circuit is not ready for use in the electrowinning tank house.
- The separation of the organic and the electrolyte is not 100%.
- Droplets of electrolyte are entrained in the organic and droplets of organic are entrained in the electrolyte.
- There may also be suspended solids from the extraction stages present in the organic and some of them will transfer to the electrolyte.
- The electrolyte must be filtered to remove these contaminants before it is sent to the electrowinning tank house.

Electrolyte Filters

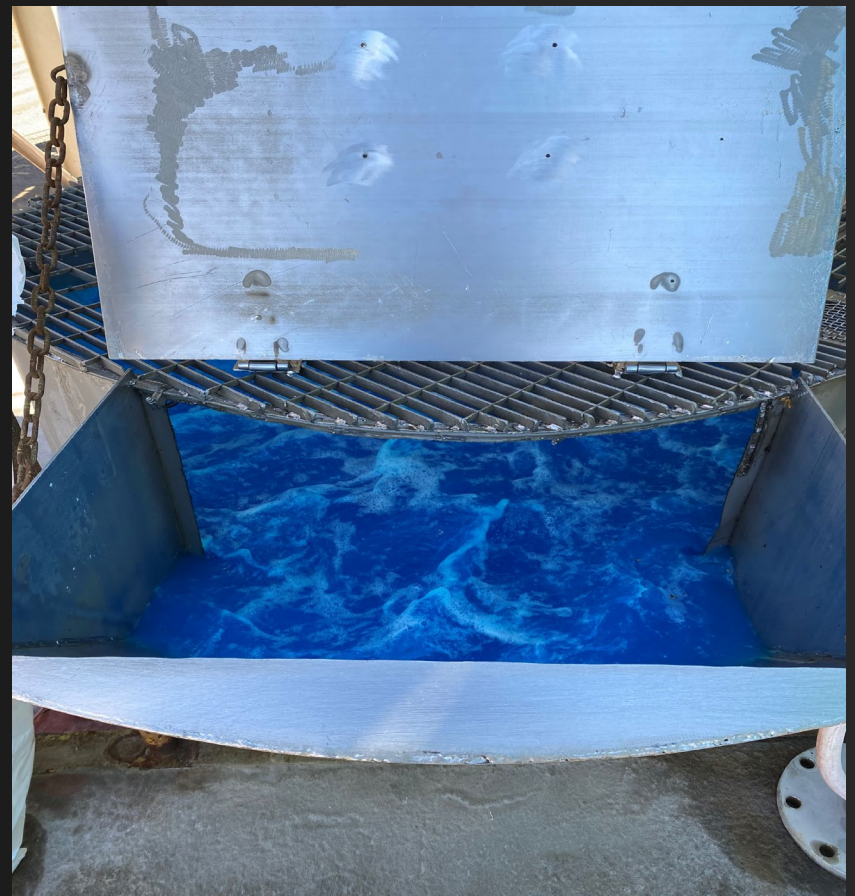
- The purpose of filtering the electrolyte
- Electrolyte filters use a layer of Sulcofloc to coat the outside of the filter screens.
- Sulcofloc works by a process called adsorption.
- The organic is attracted to and clings to the surface of the Sulcofloc. Taking the organic out of the electrolyte.

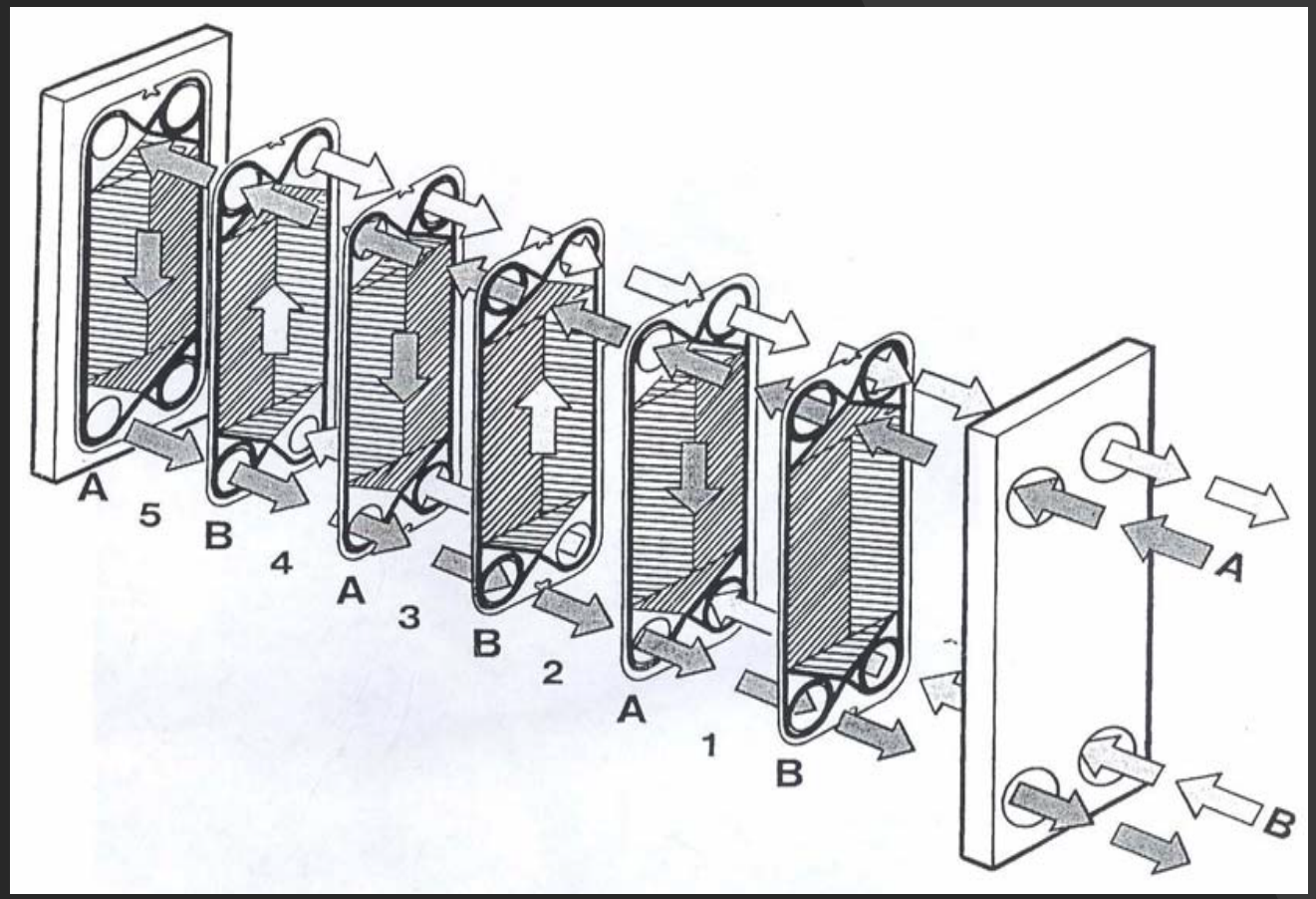
Heat Exchangers

- Passing the filtered rich electrolyte through a heat exchanger.
- The heat exchanger is typically the plate style.
- Sheets and gaskets are configured so the cooler rich electrolyte from the electrolyte filters passes on one side of the sheet and warmer solutions pass on the other side of the sheet.
- The heat exchanger works on the principle that heat moves from a place of higher concentration to a place of lower concentration.



- The electrolyte is preheated to reduce electrical resistance and maintain temperature in the desired range necessary for the chemical reactions. If the electrolyte temperature is too low, excess electrical energy will be used in the electrowinning process.
  - Higher temperatures reduce the void space (air pockets) in the cathode, allowing the copper to strip easier from the blank.
  - A five-degree temperature swing can cause a significant lead upset.
  - For every 20-degree Fahrenheit increase in temperature, the corrosion rate of the anode doubles.
  - A Fine Line: Too high of a temperature will make anodes corrode, but too low of a temperature will make a poor copper deposit.





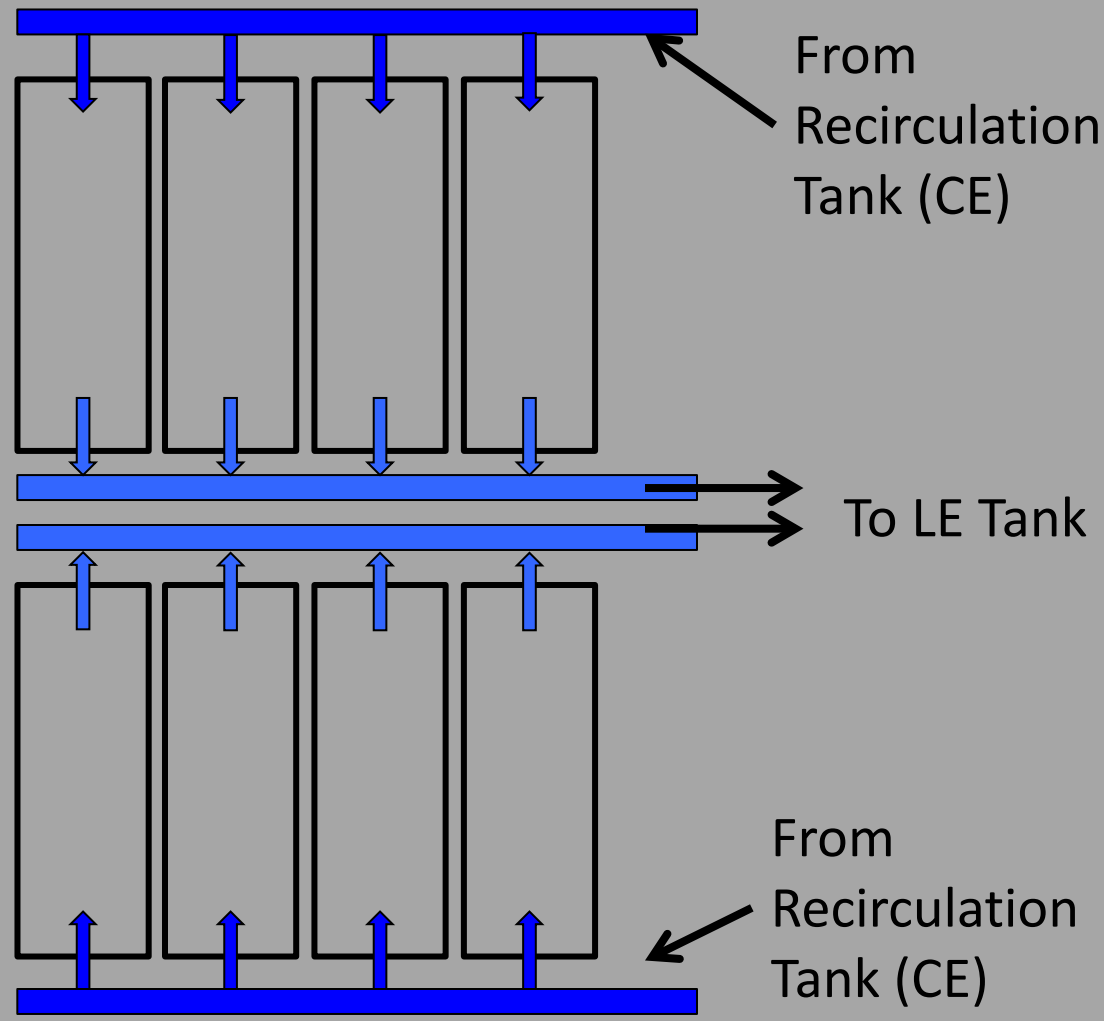
Electrolyte Requirements

- At this point in the hydrometallurgical process, the electrolyte is finally ready for the electrowinning tankhouse.

- The electrolyte has been:
  - Concentrated in the strip stages
  - Filtered in the electrolyte filters
  - Pre-heated in the heat exchangers

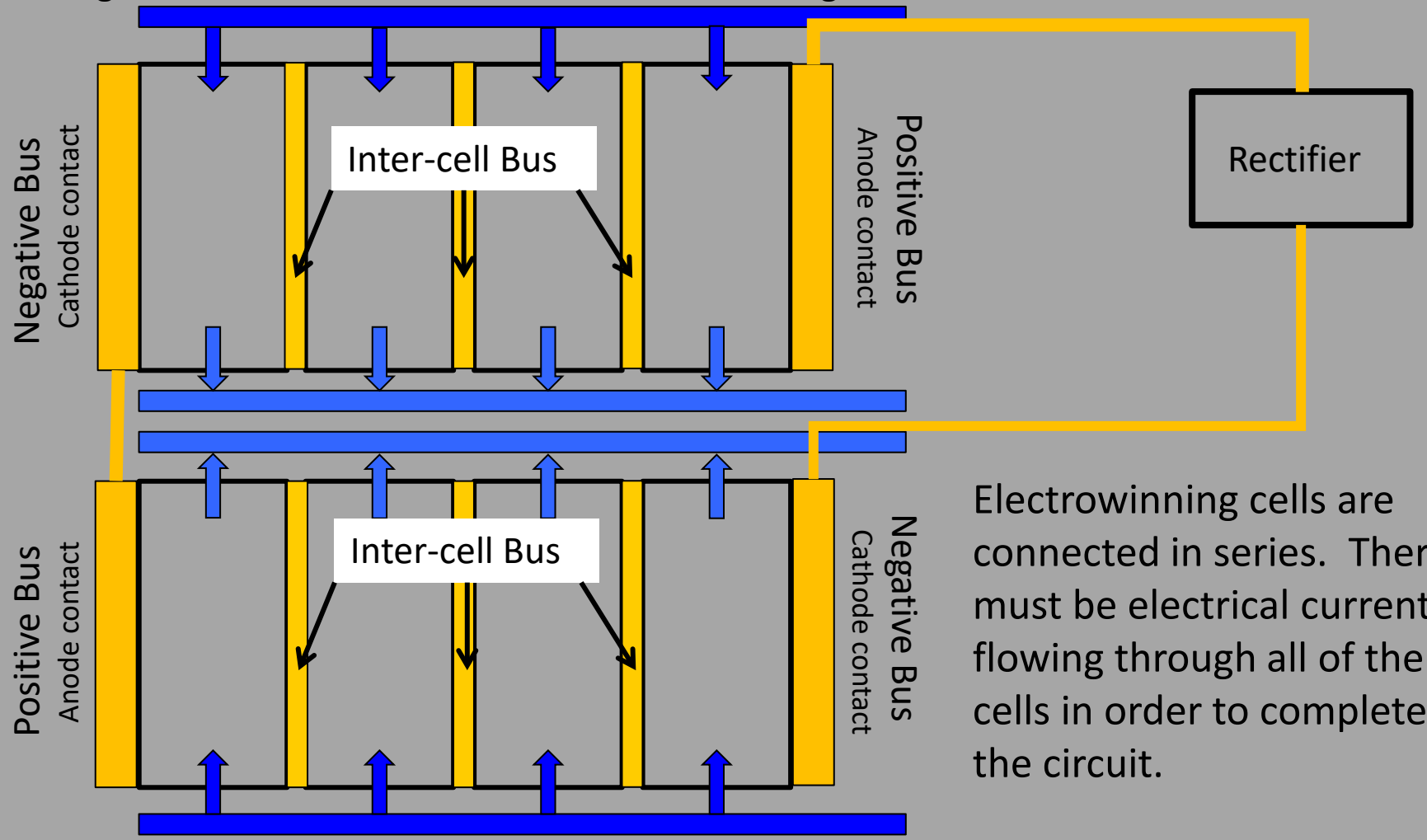
Tank house Electrolyte Flow

- A tank house consists of electrowinning cells that are essentially rectangular tanks.
- The electrolyte from the electrolyte recirculation tank flows through an inlet header, through an inlet for the individual cell, overflows through an outlet for the individual cell, into an outlet header and then back to the lean electrolyte tank.
- The overflow may have an adjustable weir to vary the electrolyte level within the cell.
  - *This is common practice in a tank house using starter sheet technology.*



Electrical (DC) Power

- The electrowinning cells need to be connected to the electrical energy source.
- The source is an alternating current (AC) to direct current (DC) rectifier.
- An uninterrupted and directional flow of electrical current is necessary to force the electro-chemical reactions.
- *AC rapidly alternates (reverses) direction in a completed circuit.*
- A transformer reduces the voltage of the incoming power, the reduced voltage feeds the rectifier.
- A rectifier changes the AC to DC and makes it an almost straight sine wave with minor fluctuations.

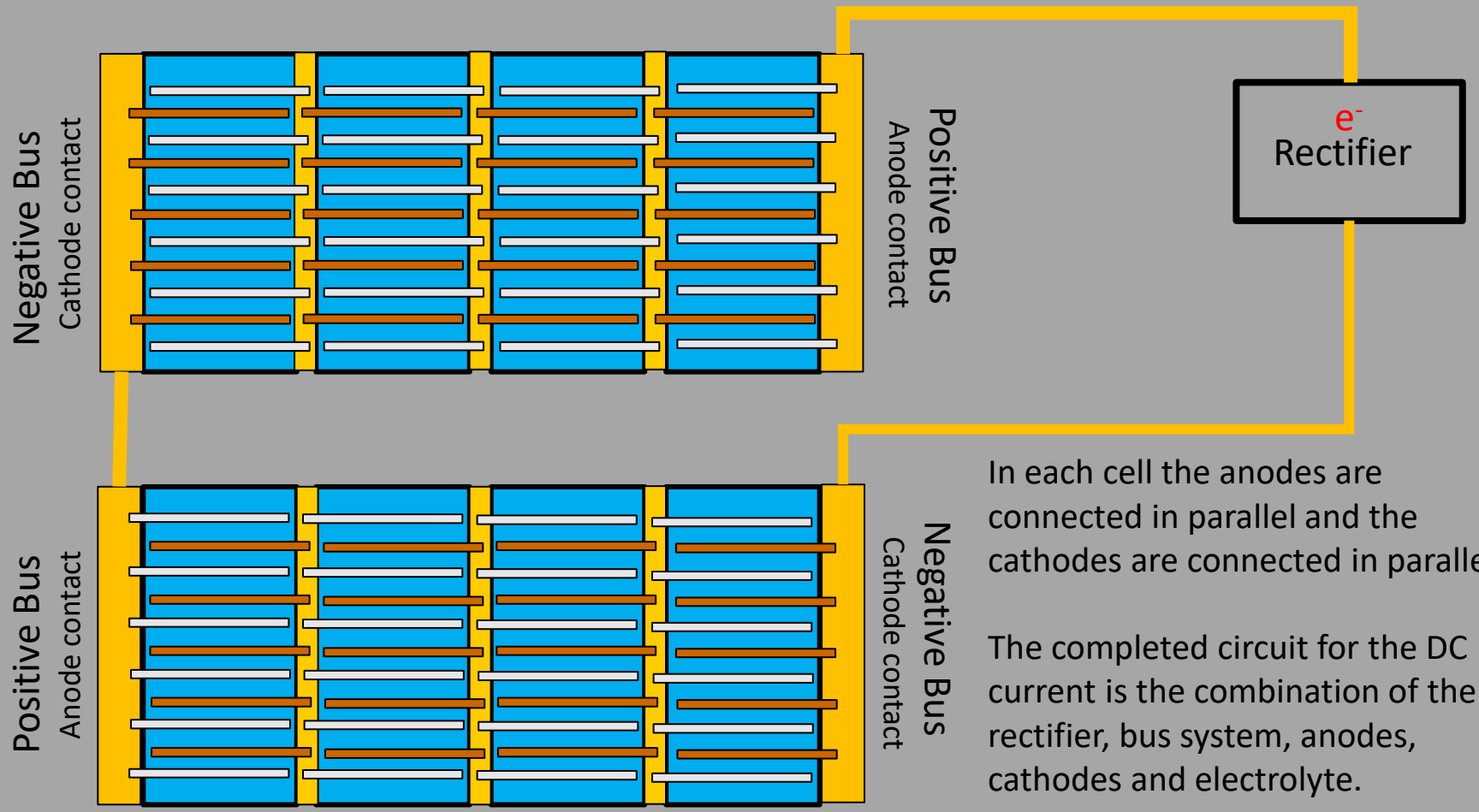


Electrowinning cells are connected in series. There must be electrical current flowing through all of the cells in order to complete the circuit.

Electrical (DC) Power

- Electrodes are required in each cell in order for the electrical current to flow.
- Within each cell, all the anodes are connected in parallel and all the cathodes are connected in parallel.
- An individual anode or cathode can fail and the remainder would continue to conduct electricity.
- The electrolyte itself is also electrically conductive.
- In an electro-chemical cell, the anode is the positive electrode and the cathode is the negative electrode.
- Electricity is normally defined as a flow of electrons.
- In an electro-chemical cell, electricity is also the flow of ions between the two electrodes.

Electrical (DC) Power

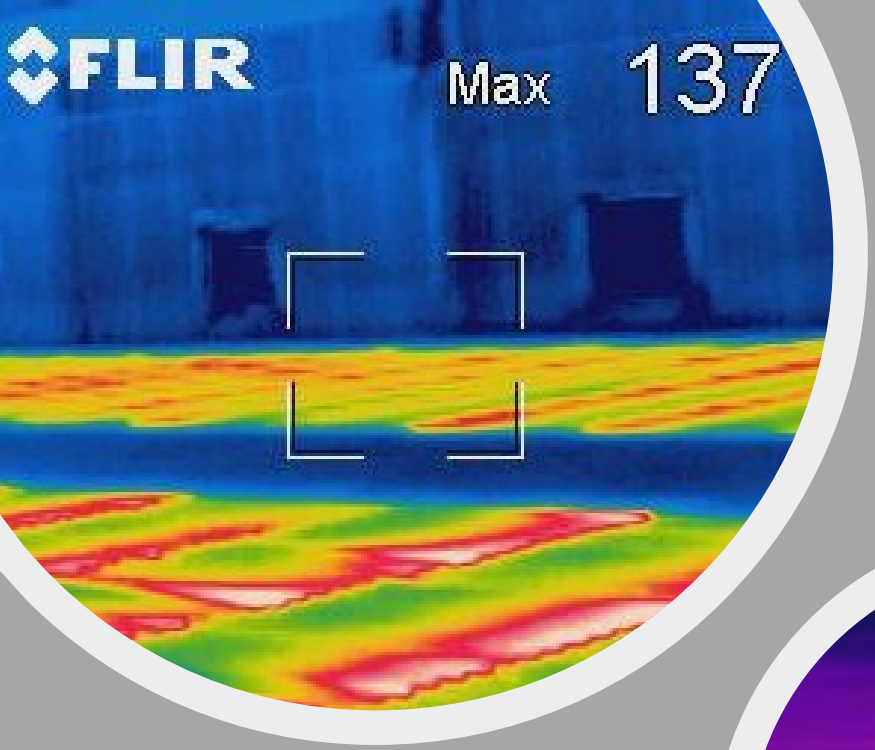


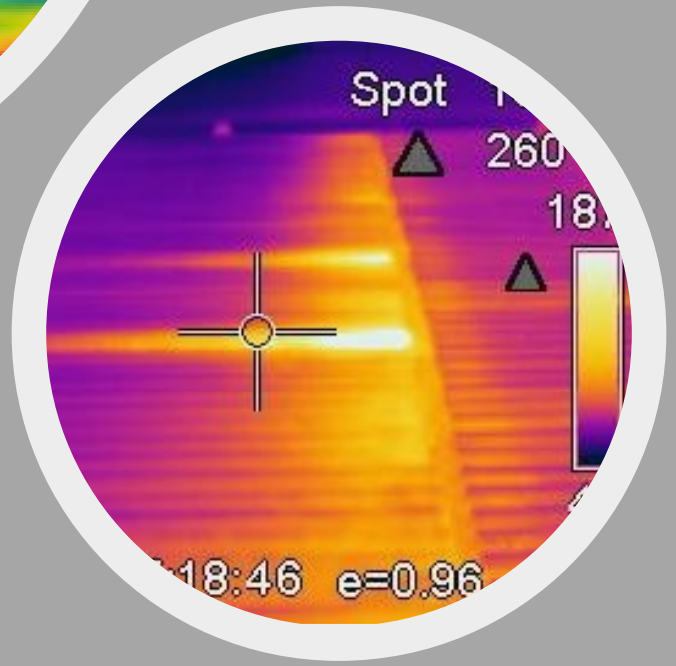
In each cell the anodes are connected in parallel and the cathodes are connected in parallel.

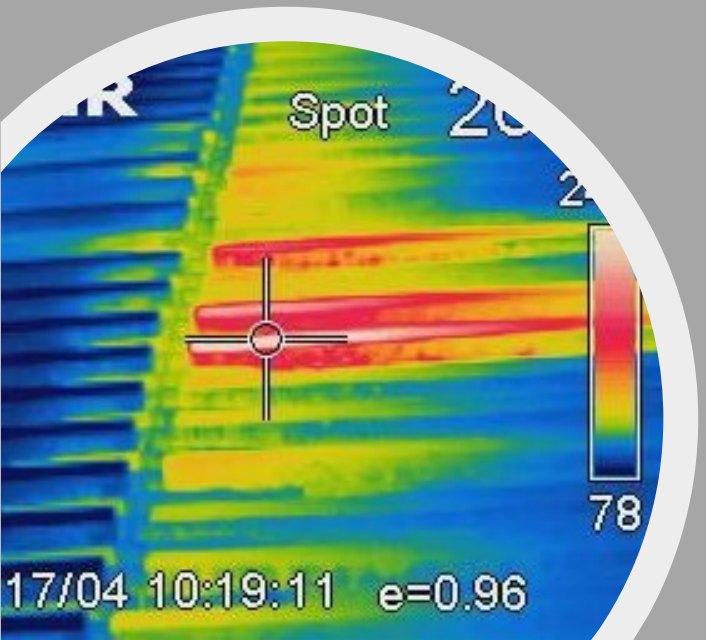
The completed circuit for the DC current is the combination of the rectifier, bus system, anodes, cathodes and electrolyte.

Short Circuit Identification

- IR Camera can be used to identify hot (shorts) or cold (no contact) anodes and cathodes.
- Cameras can be set on a color or grey scale based on personal preference.







- Water Hose Detection should only be used when an IR camera is not available.

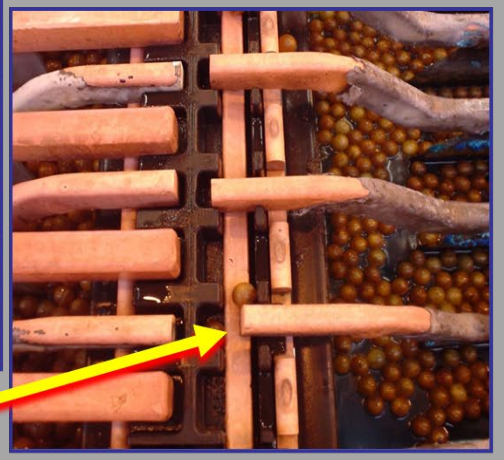
- Hot Anode/Cathode/Steam = **Short Circuit!!!!**

Current Loss: Short Circuits

- As the # of short circuits increase,…

No contact

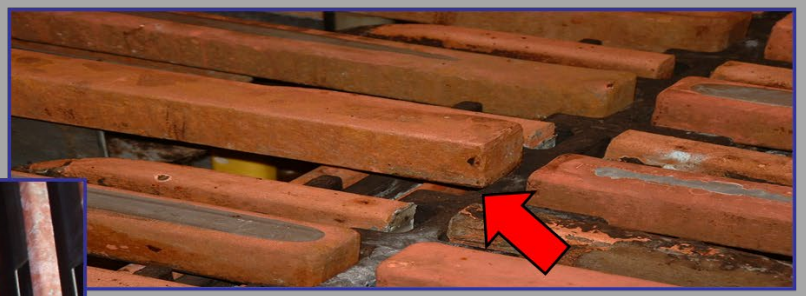
… less current is used to plate copper because it is being lost to the short circuits.

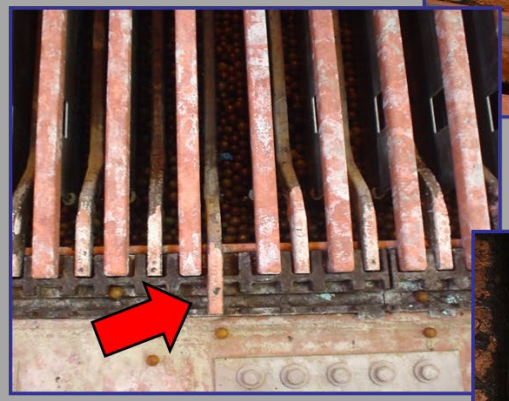


Poor placement on bus bar

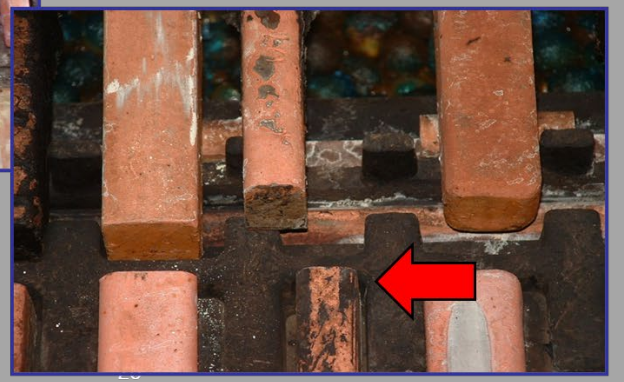
No Contact

- Anode or cathode not making contact with the bus bar





- Entire side will not have any copper plating



Inter-cell Bus

- A cap board is used to ensure that the hanger bars for the electrodes do not come in contact with each other within a cell or with electrodes in an adjacent cell.
- The actual copper conductor is shared between the cells, but the electrode hanger bars are insulated from each other.
- They also index the hanger bars to provide the needed spacing for ease of installing and removing the electrodes by means of an overhead crane.
- Several designs are in use; however, they all provide the same general function.

Types of Anodes

Two types of anodes are currently in use.

- One is made of a lead alloy and may be either cast or rolled.

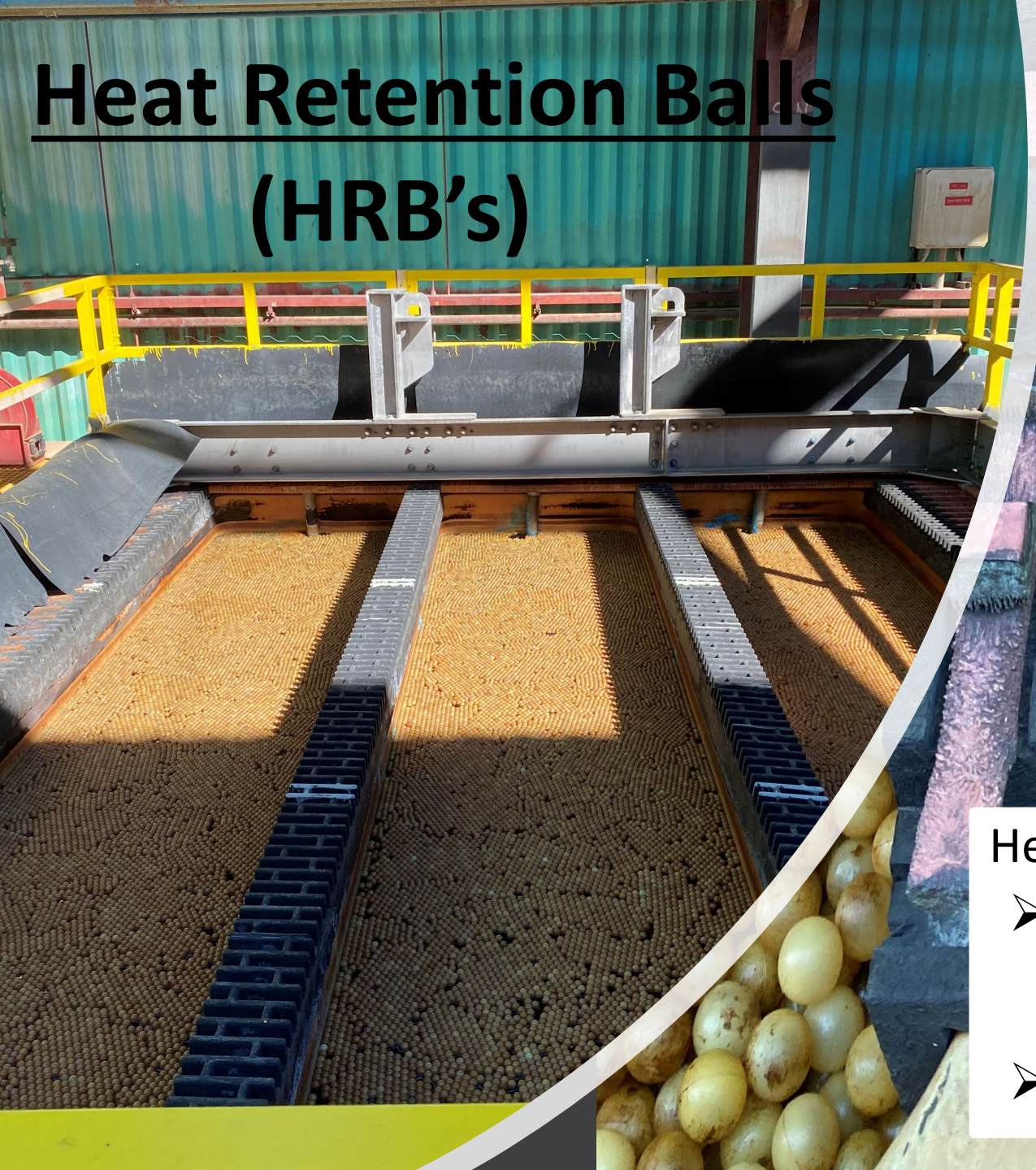
- The other is a proprietary alternative anode made of specially coated titanium mes

Types of Cathodes

- Fabricated starter sheets consist of a hanger bar, two suspension loops, and a sheet of copper.

- Blanks are a reusable stainless steel or titanium sheet with a hanger bar.

Heat Retention Balls (HRB's)



Heat Retention Balls have a dual purpose:

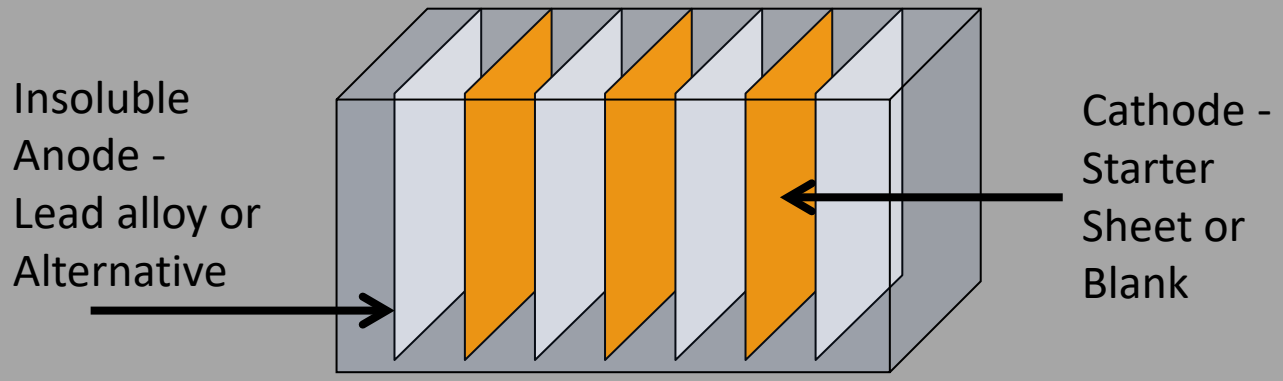
- To reduce the aerosol effect of the oxygen release in the ION exchange process and Acid Mist.
- Insulating the electrolyte to maintain heat.

Cell Electrode Alignment

Electrowinning cells that use the starter sheet technology. The anode hanger bar may be longer on one side. The starter sheets (cathodes) is moved on the hanger bar to center the sheet to the anode.

Electrodes

- The cells are loaded with the required number of anodes and cathodes.
- The cathodes require an anode on each side so that copper reduction (plating) will occur on both sides of the cathode.
- The cell will always contain one more anode than the number of cathodes.



Flows

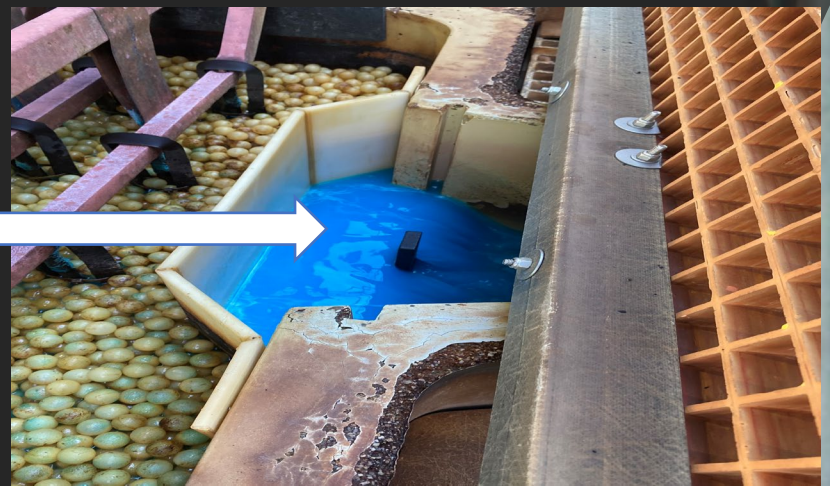
As the electrolyte flows through the cell, copper is plated out and the copper content of the electrolyte in the cell decreases. Flow through the cell is not uniform.

Discharge:

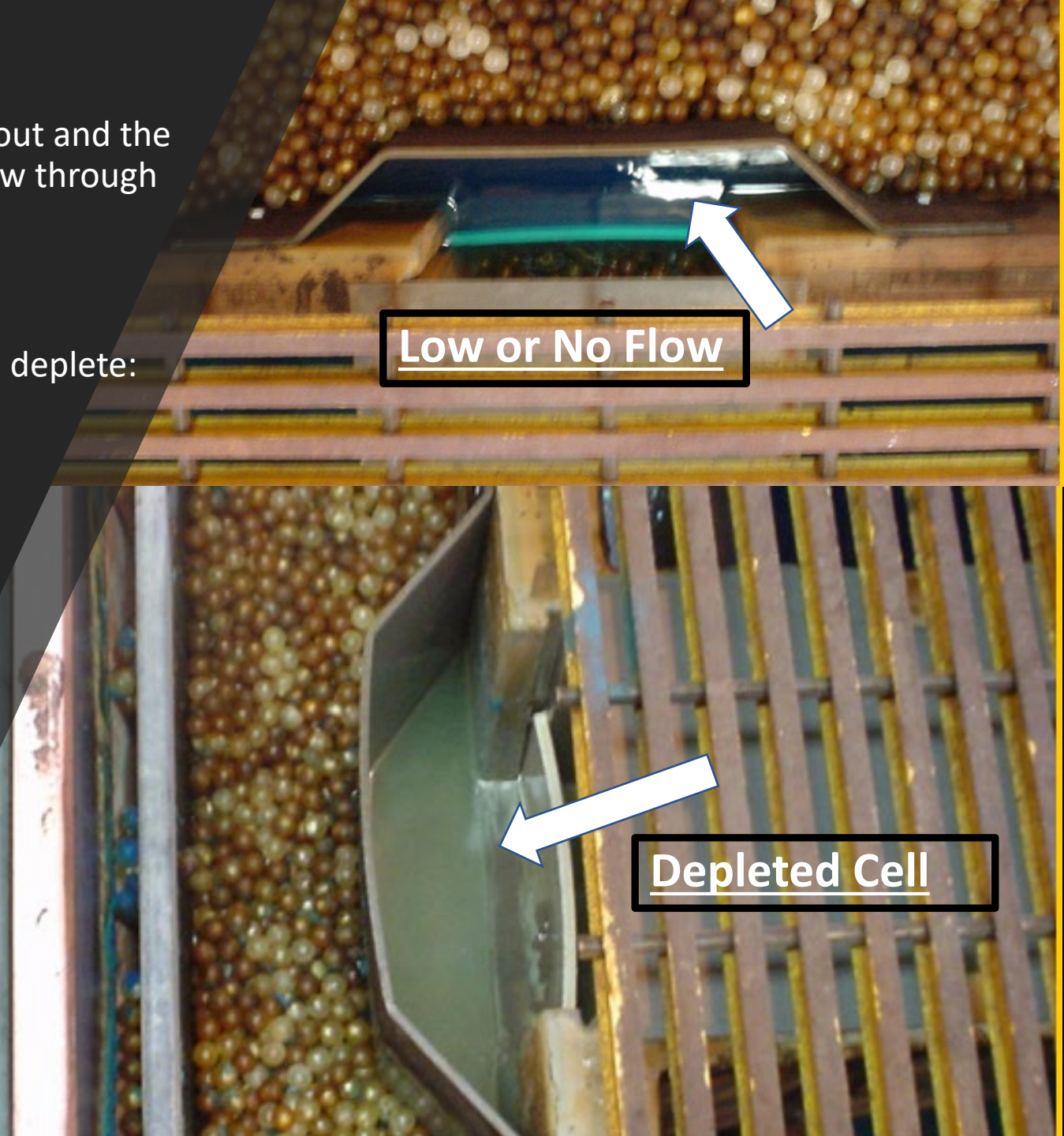
- Must maintain sufficient flow through each cell.
- Without sufficient flow, copper content in electrolyte will deplete:
  - Copper powder will be produced.
  - Hydrogen evolution can occur, which can explode!
- Solution may run clear or murky at the discharge.
- Occurs when flow is restricted into or out of the cell.
- Level in cell may decrease.

Depleted Cells:

Warning Signs of a Possible Depleted Cell



This is how the flow going out of the cell should look like.



Chemical Reactions

- Apply the electrical energy and start producing electrowon copper
- The first chemical reaction that occurs
- *Ferric* (Fe^{+3}) and *ferrous* (Fe^{+2})
- Ferric Ferrous Couple
- Completes the electro-chemical circuit

Overall Chemical Reaction

- This reaction is what is called a reduction/oxidation (redox) reaction.
- Metallic copper (Cu^0) is reduced at the cathode surface.
- The water molecule (H_2O) is oxidized at the anode surface.
- 99.9% pure electrowon cathode is what is produced.
- In the process oxygen (O^2) is liberated.

Copper Cathode

- Cathodes are sampled, assayed and assigned a metallurgical grade.
- At the end of the plating cycle, the cathodes are harvested.
- Cathode bundles are weighed and identified with a barcode label.
- The cathodes are sent to various internal and external customers for further processing.
- The majority of cathodes are sent to rod plants.