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Chemical Engineering for Entrepreneurs

Chlor-Alkali

A chlor-alkali plant is a specialized type of chemical plant operations. Using DC power, electrochemical cells split an ultrapure sodium chloride brine into its constituent components, chlorine, hydrogen and sodium hydroxide.

The plant can be separated into the following units:

1. Brine
2. Cell and Renewal
3. HCl Burner
4. Caustic Evaporator
5. Bleach
6. Utilities

The critical factor for any chlor alkali plant is the purity of the brine fed to the cells. The ability to remove low level constituents from the brine is the key to any chlor alkali operation. The following lists the brine constituent affects on chlor-alkali membrane cells.

<u>Br – Bromine</u>

1. Passes through the chlor-alkali system
2. Levels in bleach offered for sale is being closely controlled by regulatory agencies
3. Usually comes in with the rock salt

<u>Co – Cobalt</u>

1. Precipitates in the membrane near sulfonic surface and so only raises cell voltage

<u>Ca – Calcium</u>

1. Precipitates in the carboxylic layer of the membrane, this is the thin layer on the catholyte side of the membrane so the precipitate forms deep inside the layered structure of the membrane and so causes both lower current efficiency (CE) and higher cell voltage

<u>Mg – Magnesium</u>

1. Hydroxide precipitates somewhere in or on the membrane carboxylic surface depending on synergistic effects
2. Contributes to rise in voltage

I – Iodine

1. Nasty to remove
2. Most gulf coast plants do not meet the iodide specification and CE falls to the lo 90% within some months but then steadies and cells remain operable but at reduced lifetime
3. Periodates precipitate in the anode in the membrane, synergistically with cations

Ba – Barium

1. Precipitates in the membrane

NaClO3 – Chlorates

1. Will build up in the circulation loop and inhabit NaCl dissolution

SiO2 – Silica

1. Causes precipitates in the membrane
2. Water for salt dissolving and/or FRP pipes are common sources
3. Synergistic effects with cations, Al and/or organics

Al – Aluminum

1. Precipitates in the membrane
2. Synergistic effects with silica and/or organics

Mn – Manganese

1. Precipitates on anode surface in blinding deposit and subsequent substrate attach

Pb – Lead

1. Precipitates on anode surface in blinding deposit and subsequent substrate attach

SO4 –Sulfate

1. Deposits in the membrane, typically in sulfonic layer but significant build-up may extend into carboxylic layer
2. A certain sulfate concentration in brine is used to control other worse brine impurity effects

Ni – Nickel

1. Nickel hydroxide precipitates on the surface of the membrane

N – Nitrogen compounds, NH3, NO3

1. Nitrogen trichloride forms if ammonia compounds are present
2. It is questionable whether nitrates initiate formation of nitrogen trichloride
3. All the accidents with the explosive nitrogen trichloride occur in liquid chlorine
4. If we form a low level of nitrogen trichloride it will be a lower level than what accidents have seen and it should be carried into the burner and destroyed
5. Nitrates will foam the brine and raise cell voltage

Fe – Iron

1. Precipitates on anode coating surface and on the sulfonic surface of the membrane

2. High levels raise cell voltage due to blinding deposit on anode coating

F – Fluoride

1. Fluoride will attack the coating on the anode
2. Fluoride is usually from city water for comparison to what our situation might be from the ore

TSS – Total suspended solids

1. Plug up lines and tubing

Mg – Magnesium

1. Hydroxide precipitates somewhere in or on the membrane carboxylic surface depending on synergistic effects

Sr – Strontium

1. Forms a blinding deposit on the anode surface and/or deposits somewhere in the membrane depending on synergistic effects

Hg – Mercury

1. Mercury will pass through the membrane and will plate out on the cathode

Total Heavy Metals

1. Potential for precipitation in the membrane depending on synergistic effects or as a blinding deposit on anode coating surface

TOC – Total organic carbon

1. Most common effect seen is organic carbon species will foam the brine
2. A foam creates resistance in the circuit which will appear as a voltage increase
3. "Organics" is a broad term and could be one of an endless array of compounds whose effect in a chlor-alkali membrane cell might never have been experienced before for a particular compound. Other possible effects include a blinding deposit on the anode coating and/or precipitates somewhere in the membrane depending on synergistic effects

The industry has evolved into two type of cells, filter press type and sealed cell type. There are three prevalent cell manufacturers left in the industry and all three will have similar brine purification specifications.

Staffing a Chlor-Alkali Plant

A rigorous and structured training program should be initiated at least six to nine months prior to the commencement of the testing and balancing of the chlor-alkali plant. New hires should begin training both as a complete team and in the specific functional teams on the various aspects of the needed skills and operations of the plant.

A team of six chemical engineers, one of whom is a strong, organized and technically sharp leader to drive the teams deliverables and development of the understanding of the technology. Each engineer shall be exposed to the system as a whole, but should be required to specialize in one of the six unit operations areas. Each engineer should also be required to take on a second area of focus to back up the primary expert.

A team of twelve lead operators, split into four teams of three to enable 24 hour coverage should begin to train on the operations of the various unit operations that make up the plant. Similarly to the engineers, the teams shall be exposed to each area and each person shall take on a primary and secondary mastery for each of the six areas. Similar to the engineers, one of the members of this team must be a seasoned and strong operations leader shall to lead the charge of this team.

A team of six maintenance technicians led by a team of two seasoned maintenance supervisors shall train in the maintenance skill sets required for the support of the plant. The instrumentation and controls, electrical and steam specialties shall be embodied in this team.

A team of 10 specialists to this group who would be independent of any one of the groups:

a. One overall executive leader with very strong technical, organizational and leadership skills who would run the whole show. This is the most important assignment decision.
b. One admin and HR specialist for the team arrangements
c. One safety and training coordinator
d. One electrical engineer to specialize in the high voltage DC systems
e. One mechanical engineer to specialize in the cell mechanical systems and maintenance procedures
f. One instrumentation and controls engineer dedicated to the SRU
g. An analytical chemistry team made up of four professionals. Two analytical chemists to insure the brine separations meet the needed purification specifications and two analytical technicians to insure 24 hour coverage for the operations of the systems. The analytical team of chemists and technicians will also focus on identifying, qualifying and validating the new analytical methods required to be mastered for supporting chlor-alkali plant operations

Training and Preparation of the Chlor-Alkali Team

The overall team shall spend six to eight weeks in classroom training to fully understand the operations of the various systems. The specialists (HR, EE, ME, and analytical chemistry teams) could be broken out to specific preparation of their specialized functions partially independent of the whole team. After the initial classroom training, each team shall be sent to an operating chlor- alkali plant to shadow, learn and integrate their classroom knowledge into the practical operations of a chlor-alkali plant. If no suitable plant locations can be found, then a pilot cell house shall be set up at the site and the teams shall progress through a series of vendor locations of test systems on each of the six major functional areas of the plant. This practical hands-on training shall last 4 to 6 months to enable the leaders, engineers, operators, maintenance technicians, and specialists to be ready to participate in the testing and balancing efforts of the new plant. A chlor-alkali plant cannot be successful without a fully qualified and staffed team in place.

This effort must have a strong hands on leader who will hold accountable all the members to build their skills based upon the knowledge that will be shared and developed within the team.

One of the most important aspects of this team training will be a month of team building where the whole of the group is subjected to chemical emergency response training. This should include everyone including the specialists. This should occur for a month long training and practical scenario execution at one of the prominent chemical emergency response training centers in the United States. All response, entry, IC and decon procedures and scenario resolution and hazard response procedures must be fully qualified prior to the TAB effort at the end of construction.

It is critical to begin to plan this overall effort immediately as time is near to where this team must be fully functional to accept the operations of the chlor alkali unit.

Typical Course Operational Training Resources

These documents will be complied and organized by the course organization. The appropriate vendors or partner engineering firms usually provide the source documents are part of the turn over packages. The course curriculum developers will use the source information to populate the training modules that will make up the course syllabus.

Training Curriculum

1. Material Safety (HAZCOM, MSDS, Company Standards, PSM)
    a. Identify all materials used in facility
    b. Compatibility of materials - equip, pipe, etc
2. Environmental
    a. Regulatory Requirements (CalEPA / EPA, etc)
    b. Company Standards
    c. Site Specific Requirements / Plans / Procedures
3. PPE Requirements
    a. Company Standards
    b. Manufacturing Recommendation
    c. Chlorine Institute – use as resource / basis
4. Unit Operations
    a. startup, normal, shutdown, maintenance and emergency
    b. Subsystems - Equipment Specific within Units
5. Management of Change
    a. Standards
    b. Process
    c. Procedures
    d. Documentation
6. Incident - Emergency Response (Spills / Releases)
    a. Air Quality / Air Releases
    b. Company Standard
    c. Chlorine Institute – use as resource / basis

Operational Documents, Reference Documents and Training Materials

Operational Documents for each piece of equipment and unit operation shall include:

1. Design Basis Documentation
    a. Scope
    b. Conditions
    c. PHAs
2. System Operation
    a. PFD's
    b. P&ID's
    c. Control Narratives
    d. PLC, SCADA documentation (annotated)
    e. Construction & Installation Documents
3. Equipment / Materials
    a. List of all equipment/materials
    b. Manufacturer's operation & maintenance manuals
    c. Parts Lists (recommended & complete list)
    d. Purchase Documents
    e. Cut Sheets
    f. Cal Sheets
4. Standard Operating Procedures
    a. startup
    b. normal operation
    c. shutdown
    d. maintenance
    e. preventative maintenance
    f. emergency (shutdown, release, spill, etc))
5. Environmental
    a. Site Specific Plans / Permits (SPCC, NPDES, ….)
    b. Reporting Process/Procedures