Evaluating and Selecting Proper Chemical Mitigation Procedures and Chemistries for Internal Pipeline Inhibition

Multi-Chem Production Chemicals
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Introduction

- Intent of Presentation
  - Identify factors relevant to an effective chemical corrosion inhibition program to protect internal pipeline surfaces
  - Not intended to provide a definitive guide for the development of a corrosion inhibition program

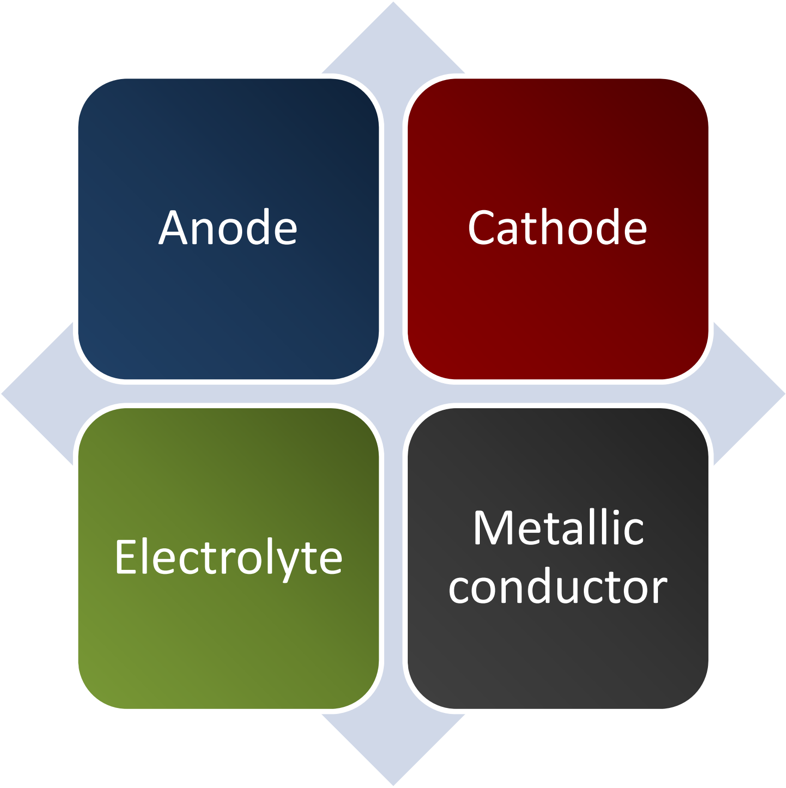
Outline

- Importance of Pipeline Integrity
- The Corrosion Cell
- System Evaluation
- Chemical Mitigation Practices
- Chemical Selection

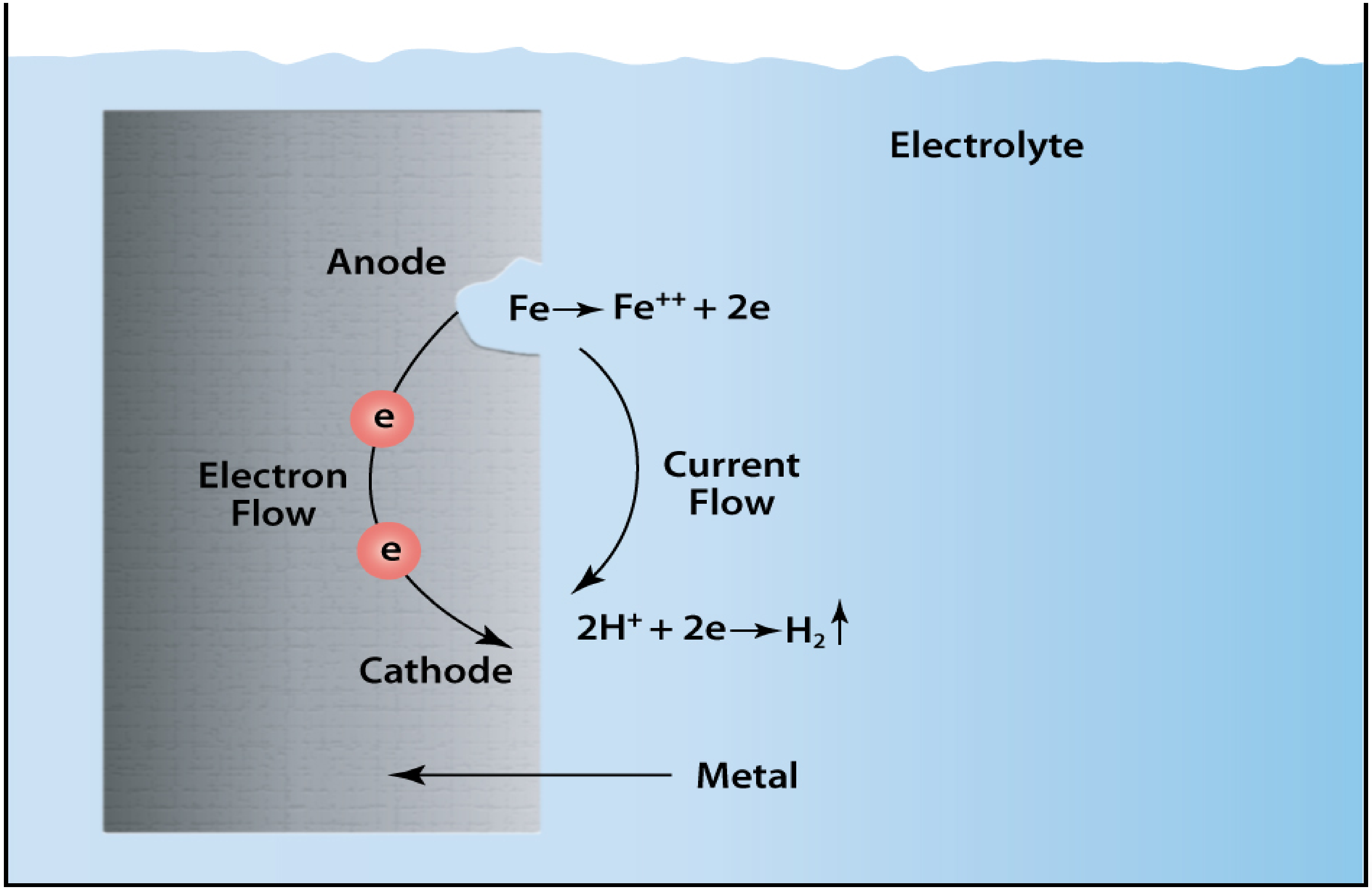
Importance of Pipeline Integrity

- Regulatory Compliance
  - Pipeline corrosion mitigation plan required unless system is deemed non-corrosive
- Asset Preservation
  - Proper maintenance only makes sense
- Liability
  - Consequence of failure

The Corrosion Cell



The Corrosion Cell



The Corrosion Cell

- The pipeline provides the:
  - Anode
  - Cathode
  - Metallic conductor
- Free water must be present
  - Remove the water and the system is non-corrosive
  - Dissolved salts improve conductivity

The Corrosion Cell

Chemical Corrosion Inhibitor Mechanism

Organic compounds that adsorb onto metal surfaces and change the properties of the metal / solution interface.

System Evaluation

- Understand corrosion risk and mechanisms
  - System corrosivity
  - Production type
  - Fluid dynamics

System Evaluation

- System corrosivity is affected by
  - Acid gas levels (% CO_2 and H_2S)
  - Organic acid levels (sweet systems only)
  - Operating Pressure – partial pressure of acid gases
  - TDS of the produced water – conductivity
  - Chloride levels – pitting potential
  - Temperature – ^ temp = ^ corrosion rate
  - Bicarbonates – pH “buffering” capability

System Evaluation

- Production Type
  - Sweet (CO_2)
    - Bottom of the line corrosion under low velocity conditions
      - Water separation
      - Solids settling allowing for under-deposit corrosion
    - Corrosion by-product scales have poor persistency and are unreliable as a corrosion mitigating agent
      - Easily disrupted by velocity/shear forces
    - Potential for top of the line corrosion
      - Primarily near compressor discharge

System Evaluation

- Production Type
  - Sour (H_2S)
    - Bottom of the line corrosion under low velocity conditions
      - Water separation
    - Significant under-deposit corrosion potential
      - Settled solids or elemental sulfur
    - Good persistency of protective scale
      - Still unreliable as a corrosion mitigating agent
      - Can be disrupted by methanol injection and other chemical reactions allowing for aggressive localized corrosion

System Evaluation

- Production Type
  - Emulsion/Liquid
    - Typically low pipeline velocity
    - Availability of “oil wetting” hydrocarbons
    - Water separation consideration
  - Gas
    - Expected higher pipeline velocities
    - Shear effects on corrosion inhibitor film life
    - Presence of oil/condensate and/or water

System Evaluation

- Fluid Dynamics
  - Determining velocity of production in the pipeline
    - Pipeline diameter
    - Operating pressure
    - Production volumes
  - Categorizing transport characteristics of gas and liquids in the pipeline

System Evaluation

- Low velocity pipelines (typically < 5 m/sec)
    - Phase separation of gas, oil, water, and solids
    - Liquids travel slower than gas
  - Stratified flow – liquid hold-up in low lying areas
  - Slug flow – intermittent liquid build-up and flush
    - Dependent upon topography – more prevalent in hilly terrain
  - Wave flow – continuous liquid movement in waves
    - Dependent upon topography – more prevalent in flat terrain

System Evaluation

- Moderate velocity pipelines (typically 3 – 7 m/sec)
    - Reduced potential for oil/water separation and solids settling
  - Wave flow – continuous liquid movement in waves
    - Dependent upon topography – more prevalent in flat terrain
  - Annular flow – liquids travel around the outside diameter of the pipeline while gas travels down the center
    - Reduced potential for oil/water separation
    - Effective liquid transportation at velocity approaching that of the gas

System Evaluation

- High velocity pipelines (> 7 m/sec)
    - Minimal potential for phase separation and solids settling
  - Annular flow – liquids travel around the entire outside diameter of the pipeline while gas travels down the center
    - Reduced potential for oil/water separation
    - Effective liquid transportation at velocity similar to the gas
  - Mist flow – liquids are dispersed into a mist that travels with the gas
    - Virtually no phase separation

System Evaluation

- Very high velocity pipelines (12 – 25 m/sec)
  - Erosion conditions may exist
    - Occurs at lower velocity in CO_2 systems due to poor persistency of the corrosion by-product protective scale

Chemical Mitigation Practices

- Batch Application – applied between pigs to provide a contiguous corrosion inhibitor film over the entire internal surface of the pipeline
  - Batch size determination/criteria
    - Internal pipeline surface area
      - Based on expected chemical slippage past trailing pig
      - Typically expected to be 3 to 5 mil, but dependent upon pig condition
    - Contact time between the chemical and the pipe
      - Typically between 5 and 10 seconds
      - Governed by produced fluid velocity and pipeline length

Chemical Mitigation Practices

- Batch Application Considerations
  - Changes in pipeline diameter or wall thickness
  - Pipeline laterals
    - Can introduce produced fluids into the batch train
    - Allow for chemical to divert into lateral
  - Pig condition
    - Worn lead pig may not effectively move accumulated liquids and solids
    - Worn trailing pig may allow for increased chemical slippage potentially resulting in no chemical near the end of the pipeline section

Chemical Mitigation Practices

- Continuous – injected at the beginning of a pipeline section and transported with the produced fluids
  - Continuous rate determination
    - Minimum effective concentration in water
      - Determined through testing
    - Film replacement based on internal pipeline area and estimated film loss per day
    - Gas rate in low GWR systems
      - Rule of thumb

Chemical Mitigation Practices

- Continuous Application Considerations
  - Very low velocity systems may not transport chemical effectively
  - Solubility in produced liquids
    - Water chemistry can influence
  - Pipeline laterals
    - Additional production (if untreated) can “dilute” continuous chemical concentration reducing effectiveness downstream

Chemical Mitigation Practices

- Combined batch and continuous – high risk/consequence systems
  - Continuous chemical supplements batch film and repairs “holidays” in film between batches

Chemical Mitigation Practices

- Effects of System Design and Limitations
  - Availability of pigging facilities
  - Location accessibility
    - May affect batch schedules or chemical deliveries
  - Availability of injection points
  - Availability of power or gas/compressed air to drive chemical pumps
  - Pipeline laterals and diameter changes

Chemical Selection

- Batch Chemical Characteristics
  - Strong film persistency
    - Typically oil soluble
    - Variable water dispersibility
  - Selection influenced by system corrosivity factors as well as
    - Flow regime (stratified and slug typically)
    - Pipeline velocity/shear (affects film life)

Chemical Selection

- Continuous Chemical Characteristics
  - Moderate film persistency
    - Primarily water soluble
    - Variable surfactant component for surface preparation
    - Vapor phase component possibility for top of the line corrosion inhibition
  - Selection influenced by system corrosivity factors as well as
    - Flow regime (applicable in most)
    - High shear conditions may reduce effectiveness

Chemical Selection

- Common corrosion inhibitor test protocols
  - Sparge Beaker
    - Typically CO_2/sweet conditions
  - HP/HT Autoclave
    - Sour or sweet conditions at system temperature and pressure
  - Rotating Cylinder Electrode
    - Moderate shear conditions
  - Jet Impingement
    - High shear conditions

Summary

- Many factors must be considered
- Systems are complex and unique
- Complete and accurate information allows for thorough understanding of the system
- No single correct answer – effective economical corrosion inhibition is the goal