

Erosion-corrosion Inhibition

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Erosion-corrosion

- Corrosion is the process of removing metals by chemical action, such as the reaction of CO₂, H₂S, and organic acids with metal.
- Erosion is the process of removing metal by mechanical action, such as particles of sand impinging on the surface removing metal.
- The combination of mechanical and electrochemical degradation processes is normally classified as erosion-corrosion.



Introduction

- ◆ Steels are subjected to erosion-corrosion in oilfield operations
- ◆ Techniques utilized for internal corrosion control:
 - ◆ corrosion inhibitors
 - ◆ coatings or liners
 - ◆ corrosion resistance alloy (CRA) materials
- ◆ Modify systems designs to reduce velocities and erosion.



Introduction

- ◆ Corrosion Inhibitors consist of one or more chemical components designed to retard electrochemical processes at a metal surface
- ◆ A small concentration of an effective CI is capable of retarding corrosion in an aggressive environment
- ◆ The efficiency of a CI is affected by environmental and metallurgical factors



Factors Affecting Erosion Rate

- The production of solid particles can be very damaging to surface equipment.
- Size, diameter, density, sharpness, geometry, and hardness of solids all effect erosion.
- As the particle size increases, the erosion rate increases.



Parameters Affecting Erosion-corrosion Rate

- Corrosive liquids containing solids transported at high velocities will remove the FeCO_3 scale and cause high erosion-corrosion.
- The erosion–corrosion rate is directly related to the sand rate, velocity, and system temperature.



Effects of Corrosion Inhibitors on Erosion-Corrosion

- Laboratory and field results indicate that corrosion inhibitors can retard erosion-corrosion due to the corrosive environments and impingement of particles.
- The proper dosages of corrosion inhibitors is required to control corrosion under very severe erosion conditions.



Inhibition of Erosion-corrosion

- Corrosion inhibition performance at the critical wall shear stress depends upon the type, structure, and the shape of corrosion inhibitor's molecules.
- Erosion-corrosion can be inhibited by using the appropriate type of corrosion inhibitor.
- G. Schmitt in NACE 93, Paper # 86, reported that the critical values for n-octadecylamine was about 100-150N/m². The critical values for n-octadeceny succinic anhydride was 500 N/m².



Inhibition of Erosion-Corrosion

- Duncan in Materials Performance; Volume 19, July, 1980 reported that erosion-corrosion in batch-inhibited systems occurs 1.5 times less than in an uninhibited system with the same velocity.
- This indicates filming corrosion inhibitors are very effective on pipe surfaces and will reduce the erosion caused by impingement.



Erosion-Corrosion Testing

- The laboratory studies, using flow loop tests and RCA apparatus, have shown the effects of inhibitors in the inhibition of erosion-corrosion.
- Flow loop test results, using low alloy steel in highly turbulent CO₂, brine, hydrocarbon fluids and 5% sand show that the proper corrosion inhibitor and the proper dosage greatly reduces erosion-corrosion.



Test Parameters

- Autoclave
 - Field brine and condensate with, and without sand;
 - 32 psi CO₂; 100 ppm H₂S; 160 F; 350 Pa, 72 hrs
- Flow Loop
 - Field brine and condensate with sand;
 - 32 psi CO₂; 180 F; 22 hours
 - Brine / condensate ratio: 90/10

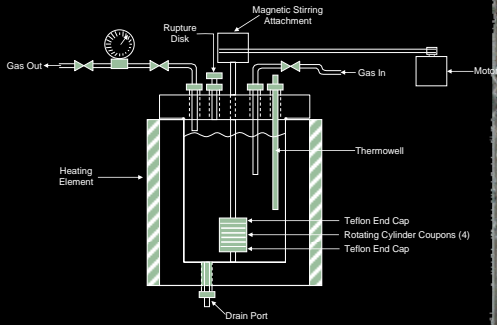


Test Parameters

Parameter	Maximum Value
CO ₂ (psi)	32
H ₂ S (ppm)	100
Temperature (F)	160
Operating Pressure (psi)	950
Condensate/Brine ratio	25/75
Acetic acid (ppm)	90
Propionic acid (ppm)	120
Velocity (ft/sec)	46
Sand (ppm)	2000



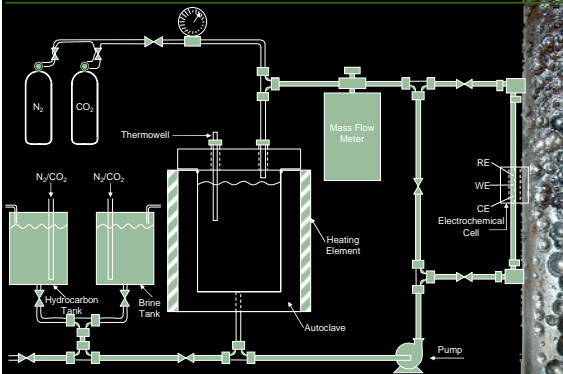
RCA Test Apparatus



RCA Test Results

Chemical (ppm)	Chemical A with sands	Chemical B with sands	Chemical A without sands	Chemical B without sands
BLANK	464.6 MPY	453.9 MPY	123.6 MPY	130.3 MPY
300 ppm	18.4 MPY	13.0 MPY	4.4 MPY	2.7 MPY
500 ppm	8.1 MPY	3.9 MPY	3.0 MPY	2.2 MPY

Flow Loop Test Apparatus



Flow Loop Test Results

Chemical ppm	Chemical B with sands	Chemical B without sands
Blank	732.4 MPY	412.6 MPY
1000 ppm	22 MPY	6.9 MPY

Erosion-Corrosion Monitoring

- Electrical resistance measurements and longer duration coupons can be used to monitor erosion-corrosion.
- The electrical resistance measurement is fast enough in high erosion-corrosion atmospheres to allow inhibitor optimization of the system.

When Inhibitors are not Practical

- The protective inhibitor film can be destroyed by hydrodynamic forces, if the flow intensity and local turbulence are severe enough.
- When corrosion inhibitors are not practical, using a non-metallic coating or CRA are recommended.

Key Steps in Coating

- Chemically/thermally clean surface
 - Effectively anchor pattern
 - Use primer systems that offer good adhesion to the steel substrate as well as good cohesion with the topcoat
 - Holiday-free application
 - The best coating in the world will not function correctly unless proper application is completed. Tubes should be visually inspected for any abnormalities to determine that they are suitable for coating.



Typical Coating Chemistries

- Epoxy
- Phenolic Resin
- Epoxy-Phenolic
- Novolac
- Nylon
- Urethane
- Polyethylene
 - These are the basic types of chemicals used in internal plastic coating. These resins combined with certain inert fillers can be adjusted to influence the temperature limit, chemical resistance, flexibility and deposit mitigation.



Coating Application

- All tubes are thermally "pickled" between 700-750 F to begin the surface preparation process. This step ashes off any remnants of organic materials, such as pipe dope or coating.
- Temperatures and times can vary due to tubular dimension and grades.



Coating Application

- Many other materials are used in the blasting process such as aluminum oxide, sand.



Quality Assurance

- 1-2 mil anchor pattern provides a perfectly clean surface of "new" metal



Coating Application

- The final bake takes place at 400-500 F to ensure a homogeneous coating (the same chemical make-up throughout). All polymer coatings must be cured at these temperatures. Thermoplastic polymer coatings, which include nylon-based coatings, are air-cured and do not require final baking.



Quality Assurance

- Wet film thickness is verified after final baking. Thin film coatings are generally under 10 mils in thickness and any coating above 10 mils is considered a thick film coating.



Quality Assurance

- Holiday test (100%)
 - The holiday test uses a wet sponge, with an ionic fluid, and electrical current to detect any thin spots or voids in the coating.



Corrosion Resistant Alloys

- Alloys, such as 25 Cr duplex stainless steel exhibited the greatest erosion-corrosion resistance. The rate of metal lost was recorded typically $1/10^{\text{th}}$ of that recorded by carbon steel.
- The most widely used CRA is 13 Cr. It has good corrosion resistance in corrosive environment and lower cost compared with duplex stainless steel.
- 13 Cr, titanium and other passive materials are protected from corrosive environments by a protective oxide film. Under erosion conditions this protective oxide film is damaged and removed from the surface exposing bare metal to the corrosive environment.



Erosion-Corrosion of 13 Cr @ 150 F

- The corrosion rate of 13 Cr in synthetic sea water at 30 ft/ sec. and 150F after two weeks follows:
 - Corrosion rate without sand : 0.2 MPY
 - Corrosion rate with 7% sand : 4.5 MPY



13 Cr Performance

- 13 Cr behaves in a similar fashion to carbon steel during periods of sand production.
- The field results suggest when film is disrupted in 13 Cr by the impingement of sand, the underlying material corrodes.



Designs Modifications

- Increasing the pipe diameter will reduce flow velocity and lowers the projection of the erosion-corrosion .
- Changing design to tolerate more sands impingement.



Conclusions

- Corrosion inhibitors can be applied to most types of corrosive systems to minimize or eliminate the erosion-corrosion process.
- An inhibitor's efficiency depends upon compositions and the corrosivity of the system.
- Inhibitors function by reducing electrochemical corrosion process and minimizing the mechanical damage by erosion.

Thank You!
