Cathodic Protection Shielding by Pipeline Coatings

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Outline

• Industry definition of CP Shielding
• Factors necessary for CP Shielding
• Issues for different coating systems
• How should CP Shielding be viewed
What is CP Shielding?

- Definition (from NACE SP0169, Control of External Corrosion on Underground or Submerged Metallic Piping Systems): Preventing or diverting the cathodic protection current from its intended path

What are the implications of this:

- The *function* of a coating is to separate the pipe surface from electrolyte, so CP is inherently shielded
- *Properly* designed coatings, which act as strong dielectrics, *should* shield CP
Why is this distinction important?

1. Regulatory reasons
   - CFR192.112: to operate at alternative MAOP:
     - **Coating.**
       
       (f) The pipe must be protected against external corrosion by a non-shielding coating.
       
       (2) Coating on pipe used for trenchless installation must be non-shielding and resist abrasions and other damage possible during installation.

     - Not clear or obvious what is meant by non-shielding coating
     - Interpretation left to individual, or to a regulator
Why is this distinction important?

2. Integrity Management

a) Pipeline Integrity is mostly managed by close interval surveys (CP potentials) and remote coating surveys – DCVG, ACVG, Pearson survey, coating conductance, others.

b) Pipeline Integrity can be managed by ILI, but only in piggable sections, and is a lagging indicator of a corrosion mitigation problem

• When CP shielding is present, must overlay (a) and (b), then identify that a problem exists

• No actual inspection tool for CP shielding, so difficult to address with integrity management plans
Function of Pipeline Coatings

• Most pipeline coatings are physical barriers by design, which isolate the metal pipeline from the surrounding environment – conductive electrolyte.

• A risk for corrosion exists at locations where (1) the coating disbands and (2) electrolyte is able to enter between the pipe surface and the coating.
  • For coatings that allow water to permeate directly, cathodic protection current may flow through the coating to the pipe surface.
  • For those coatings that do not allow for water permeation, shielding must be further evaluated.

• The main issue is not whether the stand-alone coating is an insulator, but whether the coating has a tendency to disband such that CP shielding occurs: i.e. water is present and polarization of the exposed steel surface is not possible
  • Coatings with superior adhesion to the pipe and between layers (for multilayer systems) will demonstrate a low risk of shielding CP current.
Consequences of Problematic CP Shielding

- Possibility of undetectable external corrosion if disbonded
- Extra bellhole digs required to verify CIS/ILI overlays

Corrosion due to shielding at girth weld by heat shrink sleeve
Damages from CP Shielding

• In cases where CP shielding is present, there are two degradative mechanisms:

1. Corrosion – rate will be at or less than ordinary corrosion rates in the local groundwater

2. Stress Corrosion Cracking (SCC) – rapid failure mechanism, but takes ~20 years before SCC initiates and becomes an integrity threat

• The most insidious factor for CP shielding is that it can exist for decades and will not be recognized, detected, or mitigated until an incident (Corrosion/SCC) occurs
How critical is the problem?

• All coatings, given the right conditions, *can* shield CP
• No coating will shield CP *if well bonded* to the substrate
• In the absence of electrolyte, shielding *cannot* occur
• CP shielding is, in fact, an outlier with regard to pipeline service – particular combinations of circumstances must be present
  • Don’t use the presumed possibility of CP shielding as the only selection criteria
  • **But**... shielding has been the cause of notable failures

• **Key points:**
  • All pipeline coatings will disbond to some extent
  • Coatings may disbond in such a way that they are conducive to CP shielding if other conditions are met
  • Some coatings show tendency to fail in a particular manner that may make them more susceptible to CP shielding
“Extreme” non-shielding: FBE

- BLISTERED FBE DISCOVERED UPON EXCAVATION, ELECTROLYTE FILLED
- NO CORROSION EVIDENCED, HIGH PH SOLUTION INDICATIVE OF ACTIVE CP UNDER THE BLISTERS
EXAMPLE

FBE Blisters – Microdefects Present

Defects enabling CP to permeate

**INDUSTRY CONSENSUS IS THAT FBE COATINGS DO NOT TEND TO FAIL IN SUCH A WAY THAT CP SHIELDING OCCURS**
“Extreme” CP Shielding – Polyethylene Tape Wrap

Soil stress leading to tape wrinkling and disbonding

Spiral corrosion on tape-wrapped pipelines
**THERE ARE DOCUMENTED INDUSTRY CASES OF PIPELINE FAILURES ON DISBONDED TAPE-WRAPPED PIPELINES RESULTING FROM CP SHIELDING (NEB report MH-2-95, 1996)**
Bitumenous Enamels

• Wrapped with felt/asbestos, can fail in multiple ways
  • If bitumen separates from wraps, non-shielding
  • If bitumen + wrap disbond as unit, shielding possible
2-Layer Extruded Polyethylene

• Can disbond from soil stress
• Soft adhesive allows movement of topcoat vs. primer – shielding can occur, but less common vs. tape wraps

WRINKLING
Liquid Epoxies/Polyurethanes

- Often fail by blistering – defects in blisters allow CP
- If applied very thick, failure mode less likely to be blistering, shielding possible
3-Layer Polyolefins

There are two major ways in which these coatings can fail:

1. Mechanical damage

   • Typically from backfill/bedrock/handling/excavation damage - current flow is allowed through the perforation; therefore, CP shielding is not a concern.

2. Coating disbondment

   • Polyolefin coatings do not absorb water and thus do not fail by blistering.
   • Polyolefin coating disbondment is a result of poor initial bonding, due to the use of intrinsically poor adhesives and/or substandard surface preparation/application. Disbondment is uncommon in modern 3LPE/3LPP.
   
   • 3-layer coatings have very high lap shear strength – excellent adhesion through the system
   • The most important activities for 3-Layer coatings are qualification (product system and applicator) and QA/QC throughout production.
     • With proper QC, shielding has not been a problem in 3-layer polyolefins.
Geotextile-backed Tapes

• Mastic with woven backing, allows CP through tape overlaps – no shielding problems
• Susceptible to disbonding from soil stress like conventional tapes
Current industry interests

• Lab tests for shielding

• Focus on local coating properties only – ignore the fact that a SET of conditions is what is important
Under-Appreciated Facts About CP Shielding

• CP shielding is not an inherent coating property, it is a set of conditions which must be met
  • “Proving” shielding is very difficult – always other factors

• Other features can result in CP shielding:
  • Pipe buried in area with significant bedrock
  • Obstructions – vaults, sheet underliners (tank farms)
  • Poorly designed/installed CP system

• To date, there have not been any reported cases of CP shielding in subsea pipelines
  • High electrolyte conductivity lead to low IR drop
How should CP shielding be evaluated

• Evaluate all factors involved in shielding
• Possible for shielding tendency to vary significantly along the same pipeline system
Summary / Conclusions

• CP shielding is a complex issue, it is not an intrinsic coating property

• All coatings designed to be good insulators – key is knowing how a coating tends to fail

• Historically, FBE coatings show lowest tendency to shield CP, PE tape wraps show highest tendency
Summary / Conclusions

• Laboratory tests help indicate local coating properties, but can be misinterpreted into a “go / no-go” result

• Must evaluate more than just initial coating selection to get more accurate assessment of the potential for CP shielding problems in a pipeline system